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UNIVERSITI MALAYSIA PERLIS

COURSE NAME	**ENGINEERING SKILLS**		
COURSE CODE	**ECT 111**	LAB NO.	

LAB MODULE

TECHNICAL DRAWING

LEVEL OF COMPLEXITY

1	2	3	4	5	6
KNOWLEDGE	**CEOMPREHENSION**	**APPLICATION**	**ANALYSIS**	**EVALUATION**	**SYNTHESIS**
√	√	√			

ENGINEERING CENTRE

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INTRODUCTION

The purpose of this course is to introduce the student to the fundamentals of technical drawing with an emphasis on engineering, architecture and construction applications. This course covers the use of technical drawing equipment, fundamental principles of technical drawing including sketching, dimensioning, lettering, orthographic projection and isometric drawing.

OBJECTIVES

After studying the material in this chapter, you should be able to:

i. Identify the basic tools used by the drafter.
ii. Describe the difference between the T-square, parallel rule, and drawing machine.
iii. Identify various types of lines and how they are used.
iv. Draw lines, arcs, and circle of specific size using drawing instruments.
v. Draw lines at specific angles.
vi. Read and measure with the engineer's scale, and metric scale.
vii. Draw irregular curves.
viii. Sketch parallel, perpendicular, and evenly spaced lines.
ix. Sketch a circle and arc of a given diameter.

Knowledge of the principles of geometric construction and its applications are essential to an Engineering Aid, As a draftsman, you must be able to "construct" or draw any of the various types of lines. In a line drawing, a line may be a straight line, a circle, an arc of a circle or a fillet, a circular curve, a noncircular curve, or a combination of these basic types of lines. You must also be able to construct line drawings at specified angles to each other, various plane figures, and other graphic representations consisting exclusively of lines.

1. WORK PREPARATION

Before you begin to work, you should devote some time and thought to organize your working area. Drafting furniture should be arranged so you can work comfortable y without fatigue or eyestrain. Be sure to check the lighting before you set up your drafting table. You can devise a system of stowing your equipment and supplies so that they are handy and in order.

2. WORK AREA

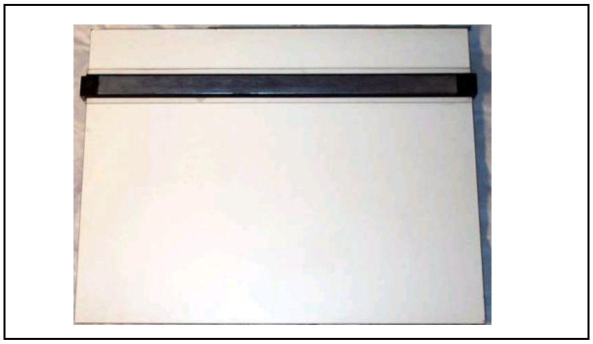
Your immediate work area should be large enough to allow sufficient freedom of movement, but not so large that you waste time reaching for equipment, supplies, and reference publications. An ideal working area allows each draftsman approximately 90 sq ft of space, although you may actually have more or less depending on the total area of the drafting room and the number of draftsmen who will work there. If you are easily distracted, do not butt your drafting table up against and facing another draftsman's table. Ensure that you have adequate lighting. The best light for drafting is natural light coming over the left shoulder and from the front left to avoid shadows cast by your hands, T square or parallel ruling straightedge, and triangles. Avoid a glaring light as it will cause eyestrain. Your drafting table height should be from 36 to 40 in. above floor level. Your drafting chair or stool should be high enough that you can see the whole drawing board, but not so high that you have to lean over uncomfortably to draw. A slope of 1 to 8 works well for the inclined position. By shifting your body or head slightly, you should be able to look directly at any point on an average-sized drawing sheet; that is, your line of sight should be approximately perpendicular to the drawing surface. Before you begin to draw, arrange your equipment in an orderly manner. Place each article so that you can reach it easily, and keep it in place when you are not using it. A systematic arrangement is timesaving and efficient. You decrease the likelihood of accidentally dropping your tools or pushing them off the table if you keep them in order. You will find it very convenient to have a small worktable adjacent to your drafting board. Placing your drafting tools and reference publications on the worktable leaves you with an uncluttered drawing board surface. When you use the drafting board in the inclined position, a separate worktable becomes a necessity.

3. INSTRUMENT DRAWING

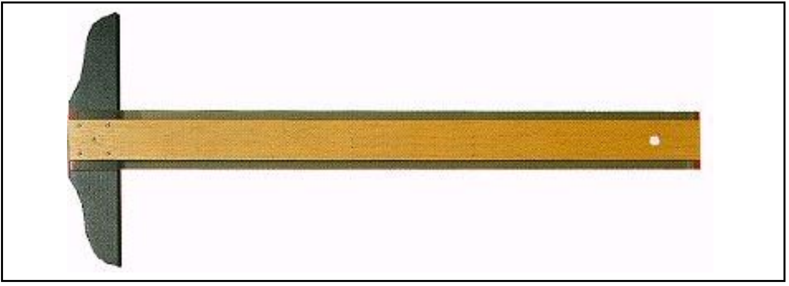
For man years the essential equipment for students and for engineers and designers in professional practice remained unchanged. This equipment included a drawing board, T-square, triangles, and a professional- quality set of drawing instruments.

The basic items of drawing equipment are shown in figure below. For the best results, the drawing equipment you use should be of high grade.

- Drawing board

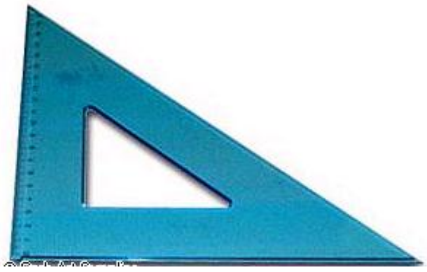


- T-square



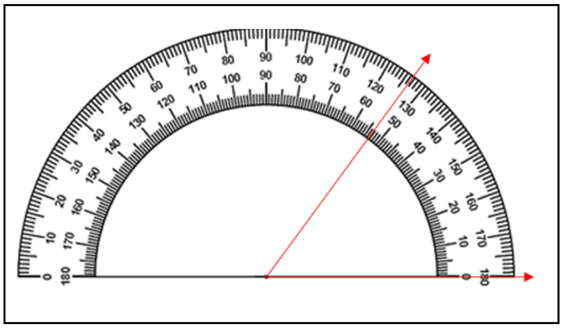
- Compass

- 45° triangle



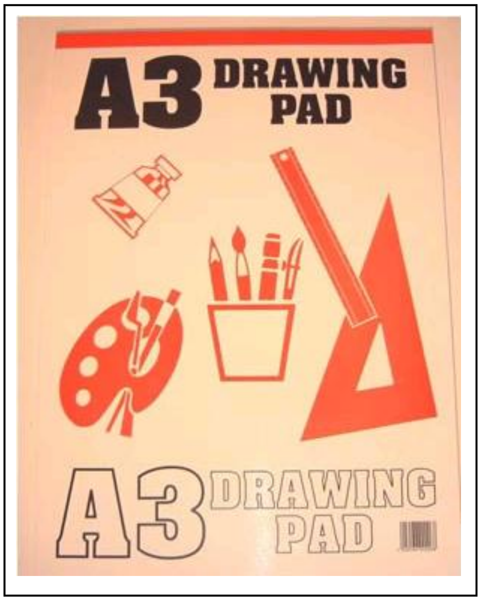
- 30° × 60° triangle

- Protractor



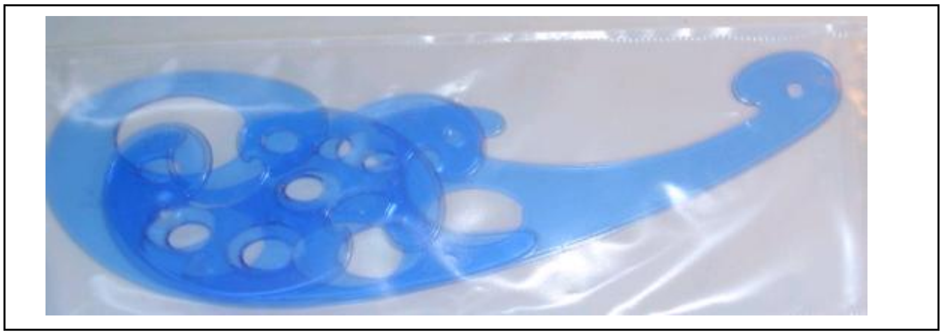
- Mechanical pencils (HB,2B,3H)
  - 9H - 3H → hard
  - 3H - B → medium
  - B - 7B → soft

- Drawing paper (A3)



- Drafting tape

- French curves



4. THE BASIC STEPS OF TECHNICAL DRAWING

4.1. ATTACHMENT OF PAPER TO THE BOARD

Now that you have become relatively familiar with your equipment and materials, it is time to get started by attaching your drafting paper to the board. The sheet should be placed close to the left edge of the drafting board. Working in this area makes the T square easier to handle and reduces the likelihood of error because of T square "swing." The drafting sheet should be far enough from the bottom of the board (about 3 in.) to ensure firm support for the head of the T square when you are drawing at the lower part of the sheet. A drawing sheet properly attached to the board on which a T square is used is shown in figure 1. After aligning the drawing sheet, smooth out any wrinkles and fasten the four corners with short strips of drafting tape. If you are attaching large sheets, you should place

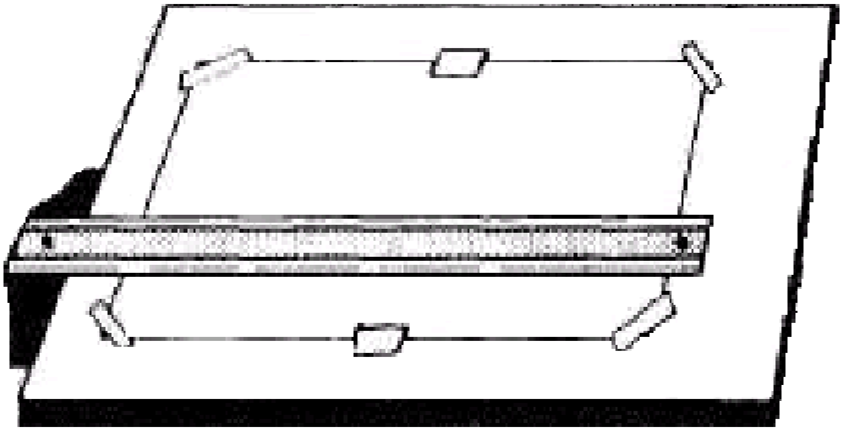


Figure 1

4.2. HORIZONTAL LINES

The draftsman's horizontal line is constructed by drawing from left to right along the working edge of a T square, as shown in figure 2, view A. This working edge, when true, is perpendicular to the working edge of the drafting board. When you draw horizontal lines, keep the working edge of the T square head in firm contact with the working edge of the drafting board. The pencil should be inclined to the right at an angle of about 60 degrees, with the point close to the junction of the working edge and the paper. Hold the pencil lightly and, if it was sharpened with a conical point, rotate it slowly while drawing the line to achieve a uniform line width and preserve the shape of the point. Normally, when a series of horizontal lines is being drawn, the sequence of drawing is from the top down

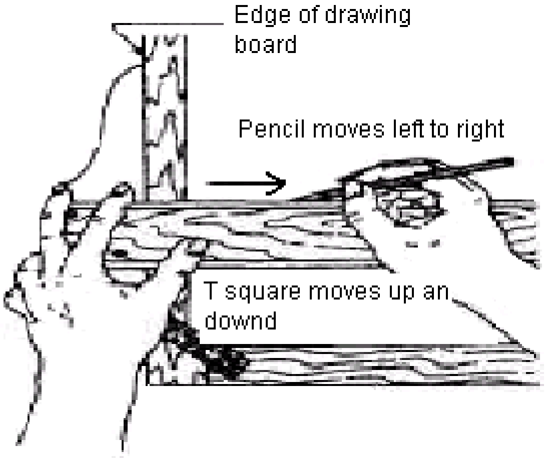

Edge of drawing board
Pencil moves left to right
T square moves up an downd

Figure 2

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4.3. VERTICAL LINES

Vertical lines are produced parallel to the working edge of the drafting board by using triangles in combination with a T square. One leg of a triangle is placed against the working edge of the blade and the other faces the working edge of the board to prevent the draftsman from casting a shadow over his work. Lines are drawn from the bottom up, as shown in figure 3, view B. The pencil is inclined toward the top of the working sheet at an angle of approximately 60 degrees, with the point as close as possible to the junction of the triangle and the drafting paper. Sequence in drawing a series of vertical lines is from left to right. At no time should the lower edge of the T square blade be used as a base for triangles.

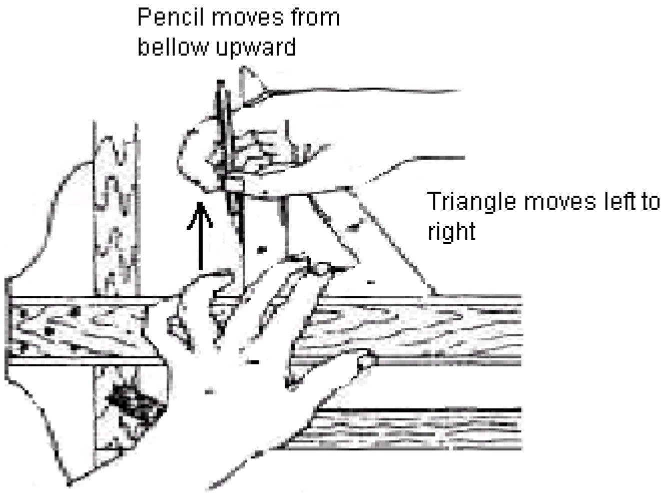

Pencil moves from bellow upward
Triangle moves left to right

Figure 3

4.4. INCLINED LINES

The direction or angle of inclination of an inclined line on a drafting sheet is measured by reference to the base line from which it is drawn. Inclined lines at standard angles are constructed with the T square as a base for triangles used either singly, as shown in views C and D of figure 4, or in combination, as shown in view E of figure 4. Used in combination with the T square as a base, the triangles serve as guides for producing lines at intervals of 15 degrees, as shown in figure 5. Used singly, the 45-degree triangle will divide a circle into 8 equal parts; the 30°/60° triangle will divide a circle into 12 equal parts. For drawing lines at angles other than those described above, you should use a protractor.

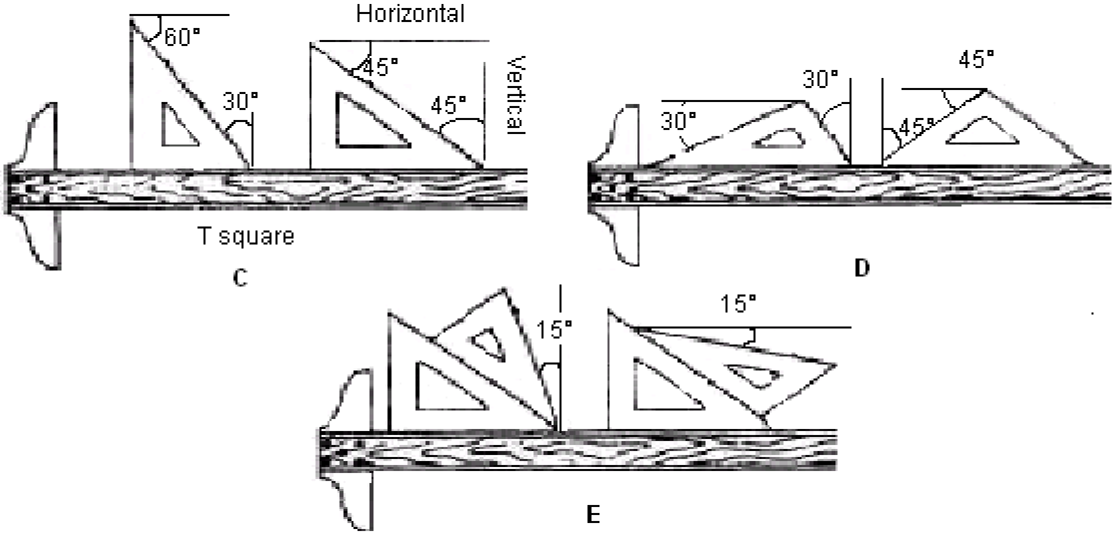


Figure 4

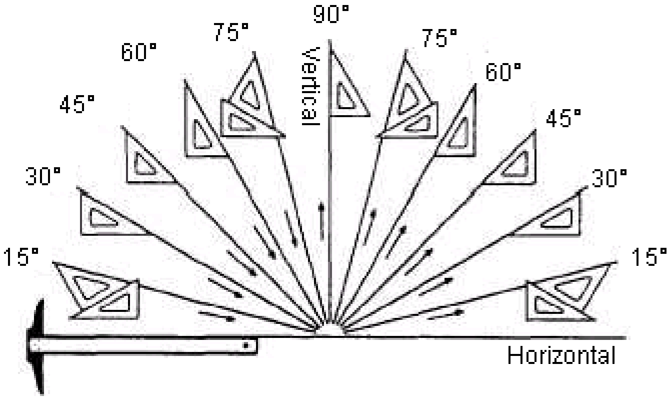


Figure 5

Using T square (or parallel straightedge) and triangles to draw lines at different angles to the horizontal. Arrows indicate the direction in which the lines should be drawn.

4.5. PROTRACTION OF ANGLES

To measure an angle, place the center mark of the protractor at the vertex of the angle, with the 0-degree line along one side. Then note the degree mark that falls on the side. To lay off an angle, position the protractor as above and use a needlepoint or a sharp-pointed pencil to mark the desired values. Then project lines from the vertex to these marks. Using only the three points on the protractor, as described above, may result in considerable inaccuracy, particularly if the lines of an angle are to be extended for some distance beyond the protractor. A refinement of the procedure is indicated in figure 6. Suppose angle BOA is to be measured. Extend line AO on to C; extend line BO on to D. When you set the center of the protractor at O, make sure that both points c and a are on line AC. Take your reading at point d as well as at point b when you measure the angle. If you are laying off the angle BOA, protract and mark point d as well as point b; this gives you three points (d, O, and b) for establishing line DB. If you are using a semicircular protractor, you can't, of course, locate point d; but your accuracy will be improved by lining up c, O, and a before you measure or lay off the single angle BOA.

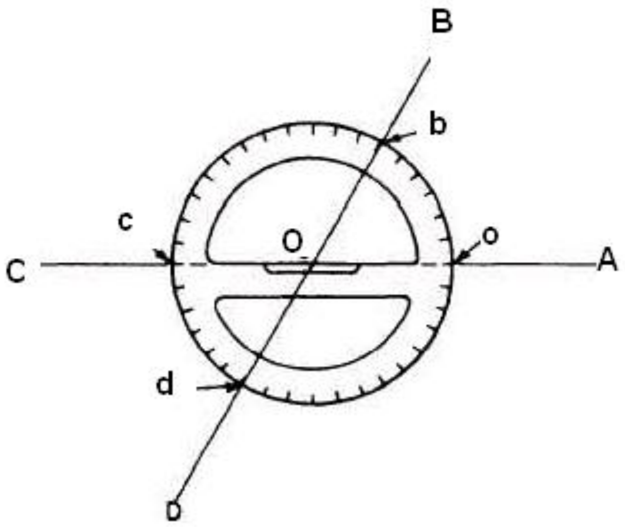
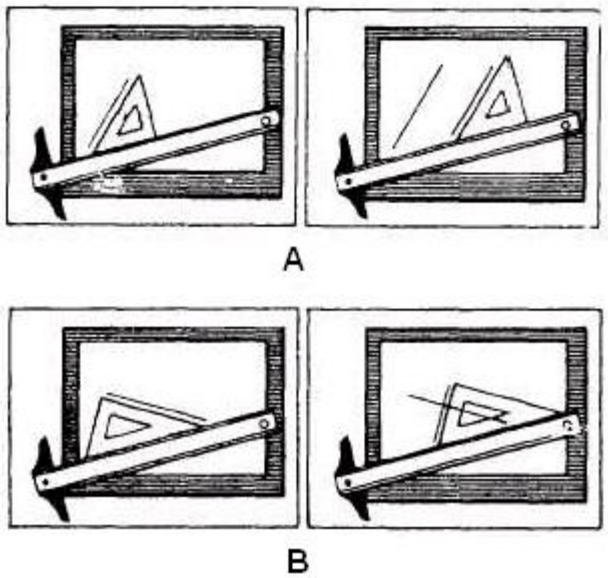


Figure 6- Protracting an angle

4.6. PARALLEL AND PERPENDICULAR LINES

To draw a line parallel to a given line (fig below view A), adjust the hypotenuse of a triangle in combination with a straightedge (T square or triangle) to the given line; then, holding the straightedge firmly in position, slip the triangle to the desired position and draw the parallel line along the hypotenuse. To construct a line perpendicular to an existing line, use the triangle and straightedge in combination, with the hypotenuse of the triangle resting against the upper edge of the straightedge (fig below view B). Adjust one leg of the triangle to a given line. Then slide the triangle along the supporting straightedge to the desired position and draw the line along the leg, perpendicular to the leg that was adjusted to the given line. In the same manner, angles with multiples of 15 degrees may be drawn, using the triangle combinations shown in figure 5

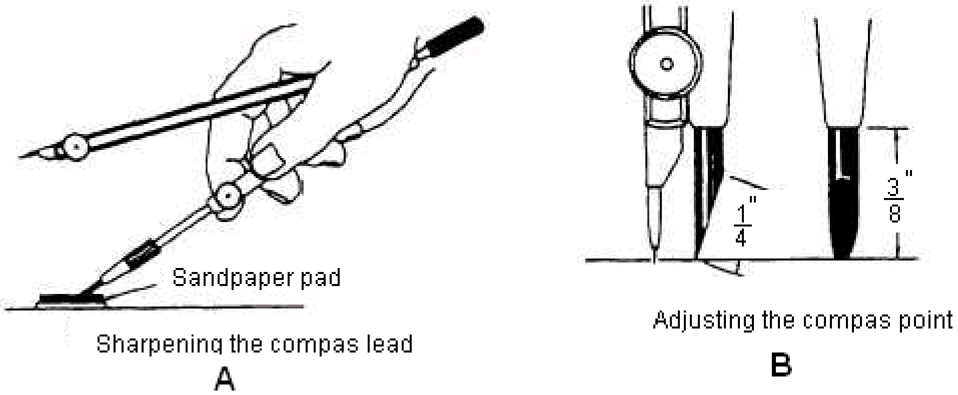


Drawing parallel and perpendicular lines

4.7. CURVED LINES

Many drawings that you will prepare require the construct ion of various curved lines. Basically there are two types of curved lines: circles and segments of circles, called arcs, which are drawn with a compass; and noncircular curves, which are usually drawn with French curves. In this chapter we will discuss only techniques for using the compass and the French curve.

When you are drawing circles and arcs, it is important that the lines produced with the compass are the same weight as corresponding pencil lines. Since you cannot exert as much pressure on the compass as you can with pencils, you should use a compass lead that is about one grade softer than the pencil used for corresponding line work. For dim construction lines, use 4H to 6H leads. Avoid using leads that are too short.



Sharpening the compass lead and adjusting the point.

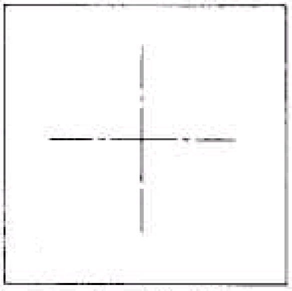
The compass lead should be sharpened with a single elliptical face, as shown in figure 8, view A. A sandpaper pad works best for sharpening compass leads. The elliptical face of the lead is normally placed in the compass so that it faces outward from the other compass leg. Adjust the shoulder-end needlepoint so that the point extends slightly farther than the lead (figure above view B). With the needlepoint pressed lightly in the paper, the compass should be centered vertically when the legs are brought together.

Bow compasses and pivot joint compasses are used in the same manner. To draw a circle with a compass, lightly press the needlepoint into the drawing paper and rotate the marking leg around it. Always rotate the compass clockwise. As you rotate, lean the compass slightly forward. With a little practice, you will find that you can easily draw smooth circles using only the thumb and forefinger of one hand. It is important that you use an even pressure as you rotate the compass. You may find it necessary to rotate the compass several times to produce a circle with a uniform dense black line

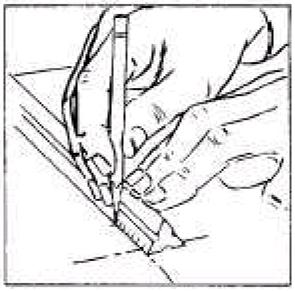
When you wish to set the compass to draw a circle of a given diameter, use a piece of scratch paper and follow the steps listed below:

1. Draw a horizontal line with a straightedge.

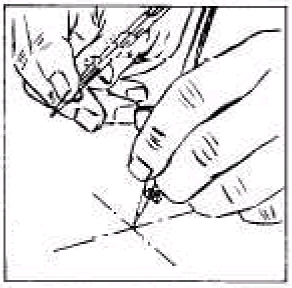
2. With the straightedge as a base, use a triangle and draw a vertical line intersecting the horizontal line.



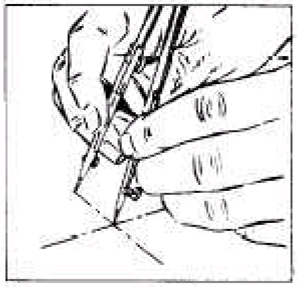
3. Measure the radius of the circle with a scale, and draw a second vertical line from this point.



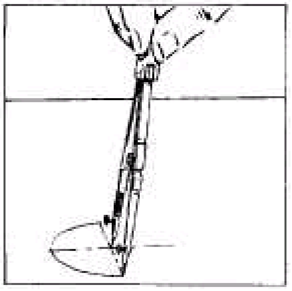
4. Set the needlepoint at the intersection of the first vertical line and the horizontal line this is the center of the circle.



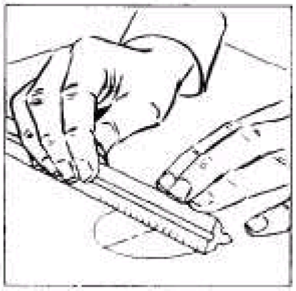
5. Set the marking leg to fall on the intersection of the second vertical line and the horizontal line.



6. Draw a half circle with the compass

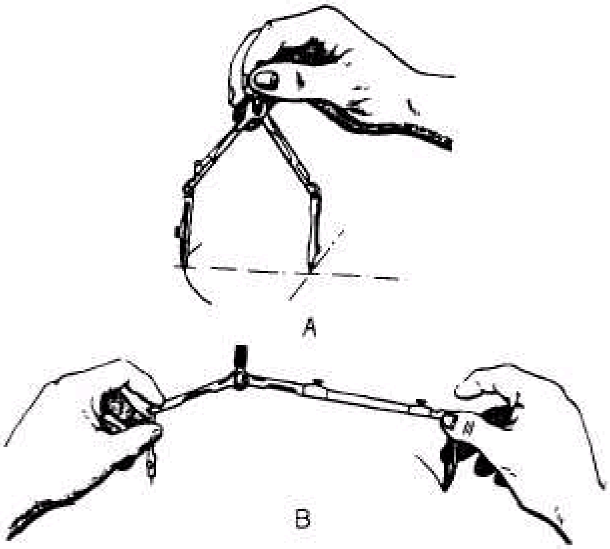


7. Check your work by measuring the diameter established by this half circle with a scale.



Once you have set the compass to the exact radius of the circle, handle it very carefully so that you don't disturb the setting. Set the needlepoint at the center of the circle and carefully rotate the compass to draw a line describing the circumference of the circle. Do not apply too much pressure on the needlepoint or it will bore a hole in the paper and you will lose the accurate center mark. To keep the diameter of the hole to a minimum, you may set the needlepoint of the compass on a small strip of paper or thin cardboard over the drafting sheet at the center of the circle.

When you are using the pencil leg to draw circles smaller than 1 in. In radius, keep the adjustable pencil and needle legs straight. For larger circles, both legs should be adjusted so that they are perpendicular to the paper. On the other hand, when you are using the compass with the pen leg, you MUST adjust it at the hinge joint to keep it perpendicular to the paper for all size circles.



Drawing a circle in ink.

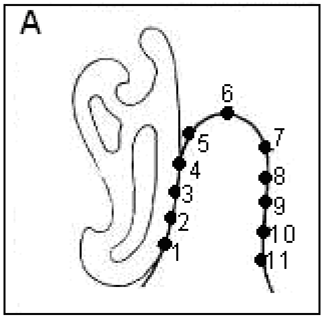
(See fig above, view A.) If the pen is not perpendicular to the paper, ink will not flow properly. To draw large circles, insert the extension bar in the pen or pencil leg, as shown in figure above, view B. When the extension bar is used to draw large circles, the process of using the compass with only one hand becomes awkward. You should use both hands, as shown in figure above, view B.

4.8. USE OF THE FRENCH CURVE

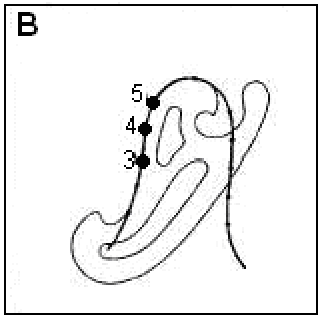
The French curve is used to draw a smooth line through predetermined points. After the points are plotted, a light pencil line should be sketched to connect the points in a smooth flowing line. To draw the finished line over the freehand line, match the various parts of the French curve to various segments of the freehand curve. Avoid abrupt changes in curvature by placing the short radius of the French curve toward the short radius portion of the line to be drawn. Change your position around the drawing board when necessary so that you can work on the side of the French curve that is away from you. You should avoid working on the “under” side of the French curve. Place the French curve so that it intersects at least two points of the line. When drawing the line along the edge of the French curve, stop short of the last point intersected. Then move the French curve along to intersect two or three more points and make sure that the edge of the curve connects smoothly with the line already drawn.

When using the irregular curve, you can draw a perfectly smooth curved line by plotting enough points (the sharper the curve, the more points you need) and by drawing in shorts steps. Below shows how a smooth line is drawn through a series of plotted points.

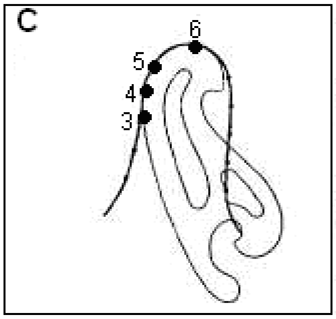
- The French curve in view A matches points 1, 2, 3, and 4. Draw a line from 1 to 3 only (not to 4).



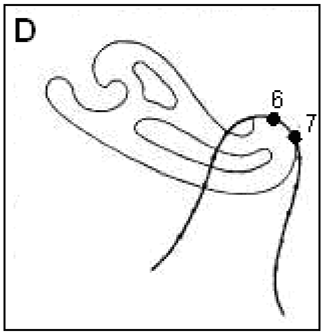
- At B, the curve matches points 3 to beyond 4. Draw a line from 3 to 4 only (not to 5).



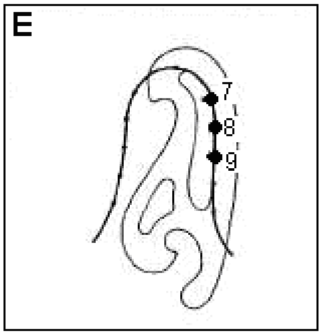
- At C, it matches points 4, 5, and 6. Draw a line from 4 to just short of 6.



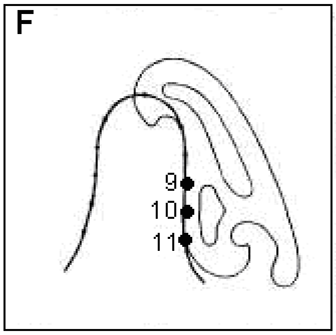
- At D, it matches a point short of 6 to beyond 7. Draw a line from 6 to 7.



- At E, it matches a point short of 7 to beyond 9. Draw a line from 7 to 9



- At F, it matches a point short of 9 to beyond 11. Draw a line from 9 to 11.



You will probably notice how the French curve is turned over and reversed to find portions that fit the points on the line with increasing or decreasing changes in curvature. When you are drawing a curved line that extends into a straight line, the curve should be drawn first, and the straight line joined to it.

5. EXERCISE 1 – GEOMETRIC CONSTRUCTION

5.1 STRAIGHT LINES

One method of drawing horizontal and vertical lines, perpendicular and parallel lines, and inclined lines is by using a straightedge (or a T square) with a triangle. Another practical method of constructing straight lines is by using a drafting compass.

Figure 7 shows a method of drawing a line parallel to another line. Here, the line is to be drawn through given point C. To draw a line through C parallel to AB, place the needlepoint of the compass on any point D on AB, and strike arc CE. Shift the needlepoint to E, maintaining the same radius, and strike arc DF. Set a compass to a chord of arc CE, and lay off the chord DF from D, thus locating point F. A line drawn through F and C is parallel to AB.

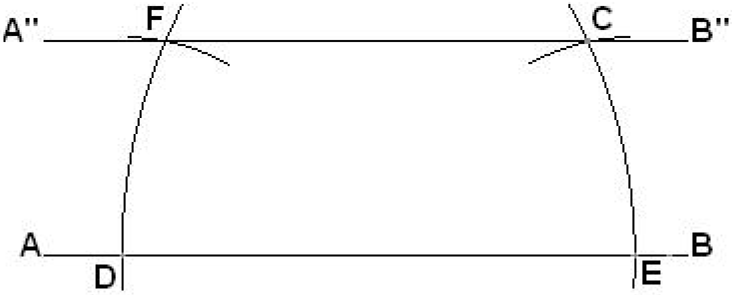


Figure 7

Figure 8 shows a method of erecting a perpendicular from a given point on a line. To erect a perpendicular from point P on AB, set a compass to any convenient radius, and, with P as centre, strike arcs intersecting AB at C and D. With C and D as centres and any radius larger than one-half of CD, strike arcs intersecting at E. A line from P through E is perpendicular to AB.

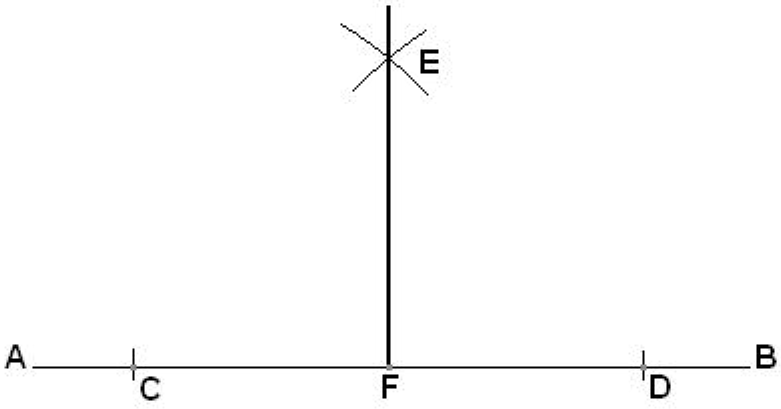


Figure 8

5.1.1 BISECTION OF A LINE

A line can be bisected by trial and error with dividers; that is, by setting the dividers to various spreads until you find one that correctly measures one-half the length of the line. Geometric construction for bisecting a line is shown in figure 9 below. To bisect the line AB, use the ends of the line, A and B, as centres; set a compass to a radius greater than one-half the length of AB; and strike arcs intersecting at C and D. A line drawn from C through D bisects AB.

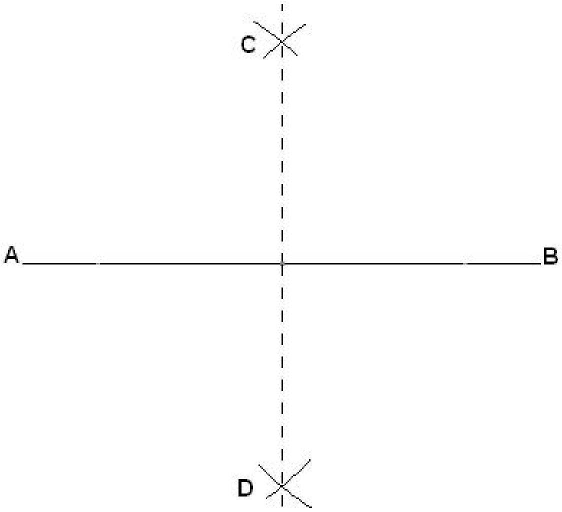


Figure 9

5.1.2 DIVISION INTO ANY NUMBER OF EQUAL PARTS

A line may be divided into more than two equal parts by trial and error with the dividers. Geometric construction for dividing a line into any number of equal parts is shown in figure 10. To divide AB into 10 equal parts, draw a ray line CB from B at a convenient acute angle to AB. Set a compass to spread less than one-tenth of the length of CB, and lay off this interval 10 times from B on CB. Draw a line from the 10th interval to A, and project the other points of intersection from CB to AB by lines parallel to the first one. The projected points of intersection divide AB into 10 equal parts.

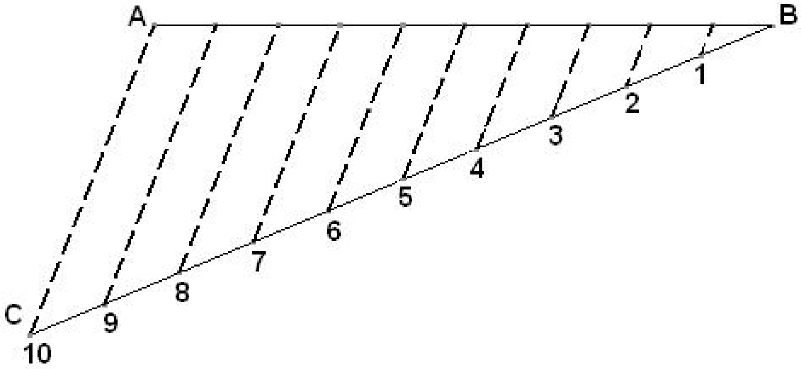


Figure 10

5.2 ANGLES

You already know how to lay off an angle of given size with a protractor, or trigonometrically by the use of the tangent or the chord method.

5.2.1 TRANSFER OF AN ANGLE

There is a geometric construction for laying off, on another part of the same drawing or on a different drawing, an angle equal in size to one that is already drawn. This procedure, called transferring an angle, is shown in figure 11. Here, the draftsman desired to lay off from O´ a line that would make an angle with B´O´ equal to angle BOA. To do this, draw an arc through OB and OA, with O as a centre, as shown in figure 11, view A. Then, draw an arc of the same radius from B´O´, with O´ as a centre, as shown in figure 11, view B. Next, measure the length of the chord of the arc between OB and OA and lay off the same length on the arc from B´O´, as shown in figure 11, view C. A line drawn from O´ through A´ makes an angle with B´O´ equal to angle BOA, as shown in figure 11, view D.

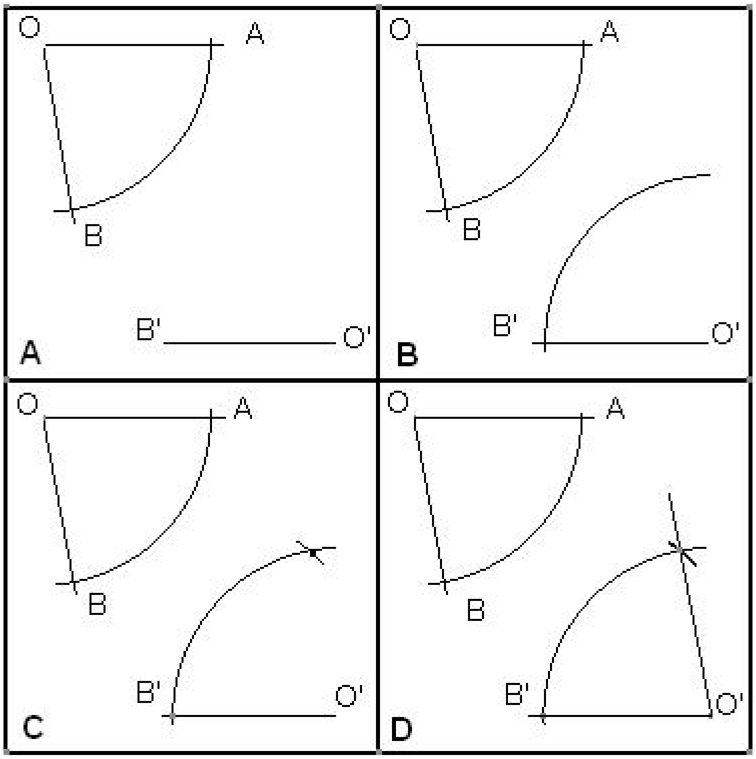


Figure 11

5.2.2 BISECTION OF AN ANGLE

To bisect an angle means to divide it in half. If you know the size of the angle, you can bisect it by simply dividing the size by 2 and lying off the result with a protractor.
Geometric construction for bisecting an angle is shown in figure 12, To bisect the angle AOB, first lay off equal intervals from O on OA and OB. With the ends of these intervals as centres, strike intersecting arcs of equal radius at P. Draw a line from O through the point of intersection of the arcs, P. The line OP bisects angle AOB.

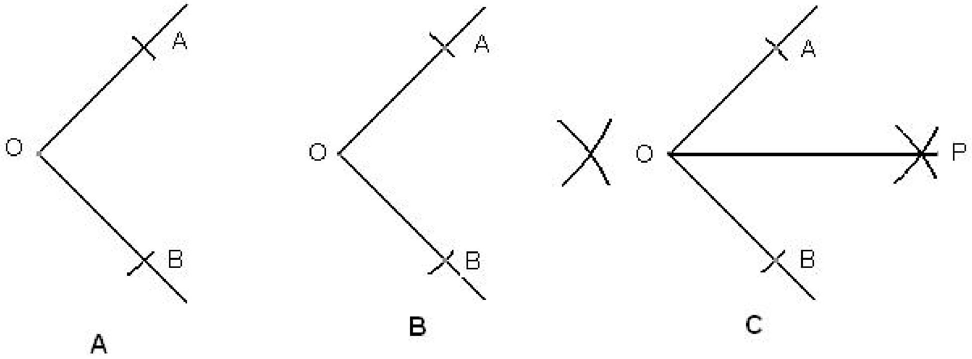


Figure 12

5.3 PLANE FIGURES

This section explains how to construct certain plane figures, such as the triangle, rectangle, square, and regular polygon. You must understand the geometrical construction of plane figures because they appear in engineering drawings.

5.3.1 TRIANGLE: THREE SIDES GIVEN

To draw a triangle with three sides given, first draw a straight line AB, equal in length to one of the given sides (figure 13). With A as a centre, strike an arc with a radius equal to the given length of the second side. With B as a centre, strike an intersecting arc with a radius equal to the length of the third side. Draw lines from A and B to the point of intersection of the arcs.

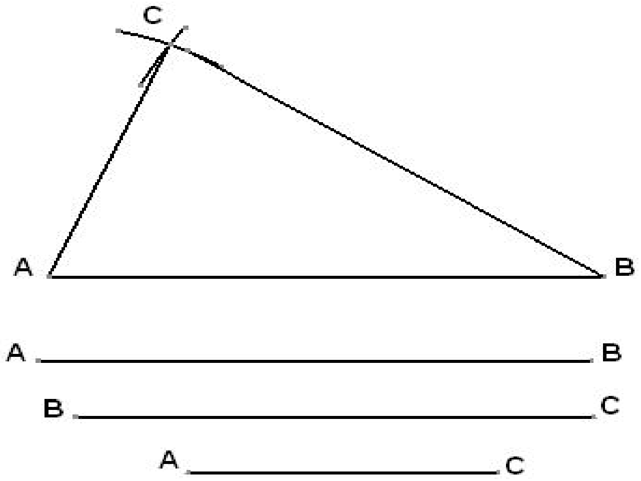


Figure 13

5.3.2 RIGHT TRIANGLE: HYPOTENUSE AND ONE SIDE GIVEN

Figure 14 shows a method of drawing a right triangle when the hypotenuse and one side are given. The line H is the given hypotenuse; the line S is the given side. Draw AB equal to H. Locate the centre of AB (by bisection), and, with the midpoint as a centre and a radius equal to one- half of AB, draw the semicircle from A to B as shown. Set a compass or dividers to the length of S, and, with A as a centre, strike an arc intersecting the semicircle at C. Draw AC and BC.

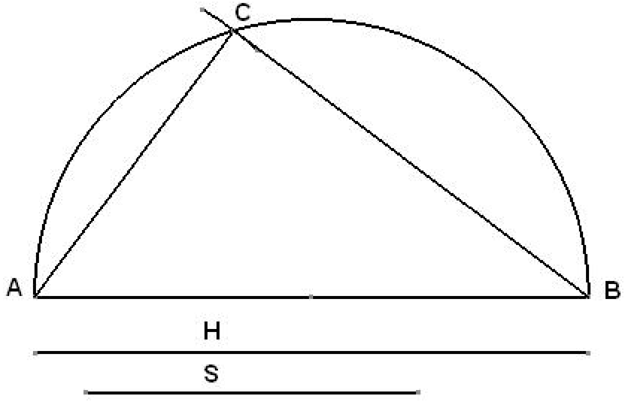


Figure 14

5.3.3 EQUILATERAL TRIANGLE IN A GIVEN CIRCUMSCRIBED CIRCLE

A circumscribed plane figure is one that encloses another figure, the circumscribed figure being tangent to the extremities of the enclosed figure. An inscribed plane figure is one that is enclosed by a circumscribed figure. Figure 15 shows you how to inscribe an equilateral triangle within a given circumscribed circle. Draw a vertical centre line intersecting the given circle at A and B. With B as a centre and a radius equal to the radius of the circle, strike arcs intersecting the circle at C and D. Lines connecting A, C, and D form an equilateral triangle.

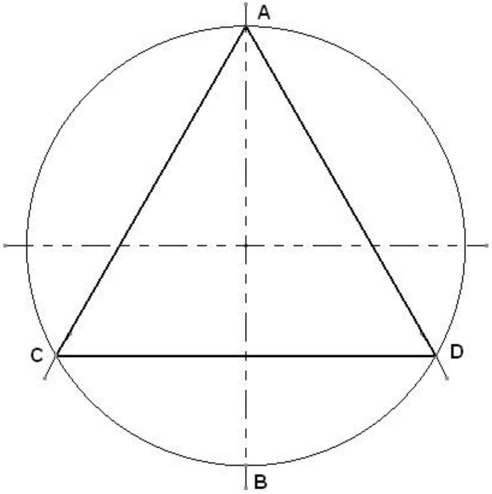


Figure 15

5.3.4 EQUILATERAL TRIANGLE ON A GIVEN INSCRIBED CIRCLE

Figure 16 shows one method of circumscribing an equilateral triangle on a given inscribed circle. Draw AB parallel to the horizontal centre line of the circle and tangent to the circumference. Then use a 30 ^{0}/60^0 triangle to draw AC and BC at 60° to AB and tangent to the circle.

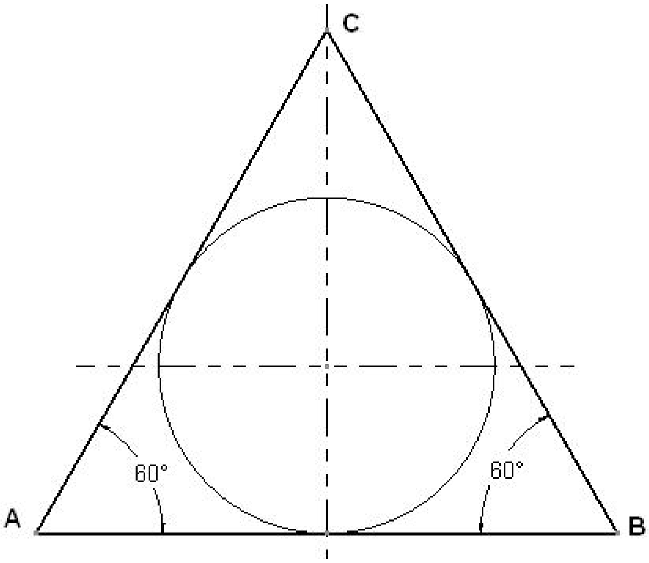


Figure 16

5.4 SQUARE

5.4.1 GIVEN LENGTH OF SIDE

You can construct a square with a given length of side by the method described for constructing a rectangle. Another method is shown in figure 17. With a T square, draw horizontal line AB equal to the given length of side. With a T square and a 45° triangle, draw diagonals from A and B at 45° to AB. Erect perpendiculars from A and B, intersecting the diagonals. Then, connect the points of intersection.

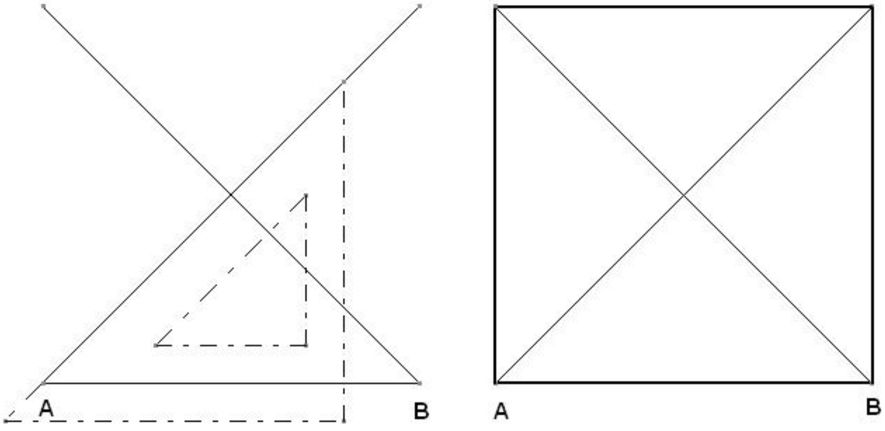


Figure 17 – Square with a given length of side

5.4.2 GIVEN LENGTH OF DIAGONAL

Figure 18 shows a method of constructing a square with a given length of diagonal. Draw horizontal line AB, equal to the given length of the diagonal. Locate O at the center of AB, and lay off CD through O, perpendicular to and slightly longer than AB. Use a T square and a 45° triangle to draw AF and EB at 45° to AB and CD, Connect AE and FB

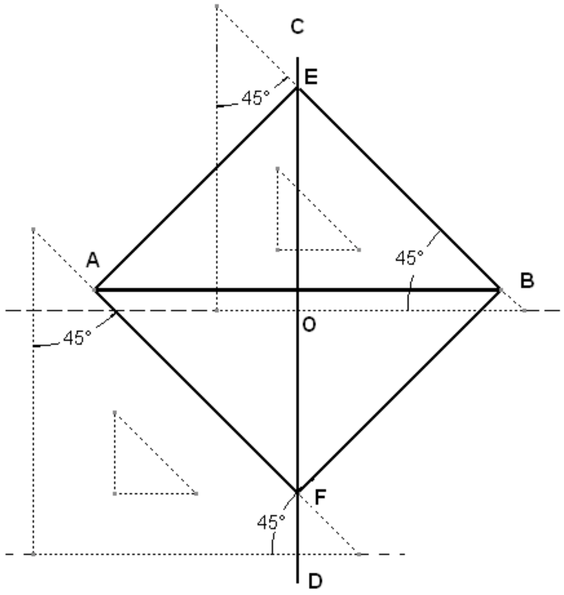


Figure 18 – Square with a given length of diagonal

5.4.3 SQUARE IN A GIVEN CIRCUMSCRIBED CIRCLE

Figure 19 shows a method of drawing a square in a given circumscribed circle. Draw the diameters AB and CD at right angles to each other, and connect the points where
the diameters intersect the circumference of the circle.

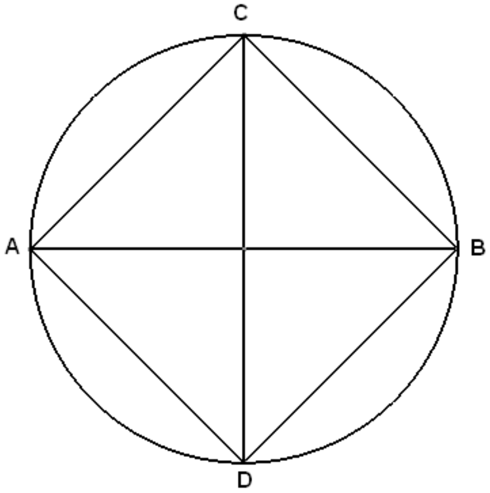


Figure 19 – Square in a given circumscribed circle

5.5 POLYGON

5.5.1 ANY REGULAR POLYGON WITH A GIVEN LENGTH OF SIDE

Figure 20 shows a method of drawing any regular polygon with a given length of side. To draw a nine-sided regular polygon with length of side equal to AB, first extend AB to C, making CA equal to AB. With A as a center and AB (or CA) as a radius, draw a semicircle as shown. Divide the semicircle into nine equal segments from C to B, and draw radii from A to the points of intersection. The radius A2 is always the second side of the polygon. Draw a circle through points A, B, and D. To do this, first erect perpendicular bisectors from DA and AB. The point of intersection of the bisectors is the center of the circle. The circle is the circumscribed circle of the polygon. To draw the remaining sides, extend the radii from the semicircle as shown, and connect the points where they intersect the circumscribed circle. Besides the methods described for constructing any regular polygon, there are particular methods for constructing a regular pentagon, hexagon, or octagon.

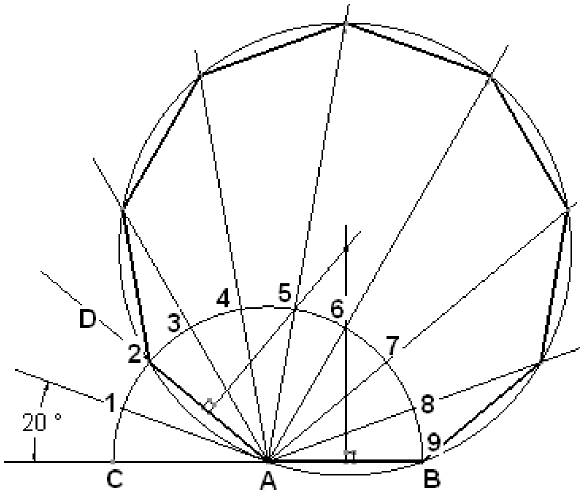


Figure 20 – Any regular polygon with a given length of side

5.5.2 REGULAR PENTAGON IN A GIVEN CIRCUMSCRIBED CIRCLE

Figure 21 shows a method of constructing a regular pentagon in a given circumscribed circle. Draw a horizontal diameter AB and a vertical diameter CD. Locate E, the midpoint of the radius OB. Set a compass to the spread between E and C, and, with E as a center, strike the arc CF. Set a compass to the spread between C and F, and, with C as a center, strike the arc GF. A line from G to C forms one side of the pentagon. Set a compass to GC and lay off this interval from C around the circle. Connect the points of intersection.

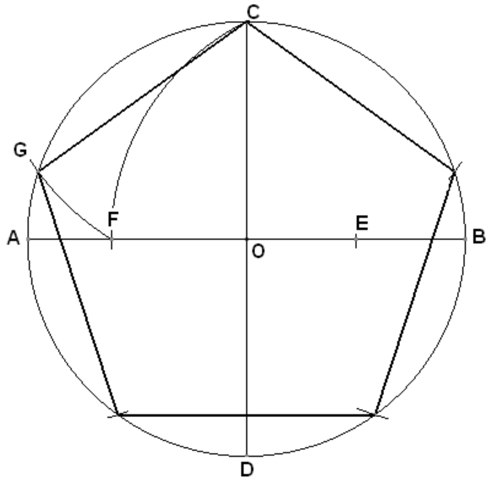


Figure 21 – Regular pentagon in a given circumscribed circle

5.5.3 REGULAR HEXAGON IN A GIVEN CIRCUMSCRIBED CIRCLE

Many bolt heads and nuts are hexagonal (six-sided) in shape. Figure 22 shows a method of constructing a regular hexagon in a given circumscribed circle. The diameter of the circumscribed circle has the same length as the long diameter of the hexagon. The radius of the circumscribed circle (which equals one-half the long diameter of the hexagon) is equal in length to the length of a side. Lay off the horizontal diameter AB and vertical diameter CD. OB is the radius of the circle. From C, draw a line CE equal to OB; then lay off this interval around the circle, and connect the points of intersection.

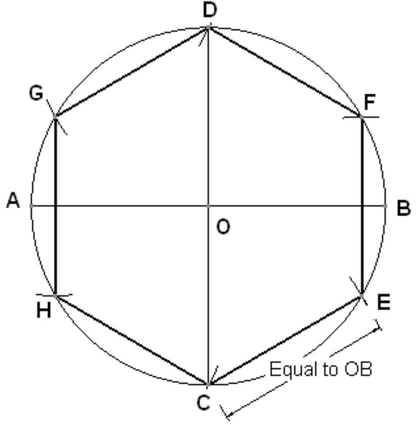


Figure 22 – Regular hexagon in a given circumscribed circle: one method

5.5.4 REGULAR HEXAGON ON A GIVEN INSCRIBED CIRCLE

Figure 23 shows a method of constructing a regular hexagon on a given inscribed circle. Draw horizontal diameter AB and vertical center line. Draw lines tangent to the circle and perpendicular to AB at A and B. Use a T square and a 30°/60° triangle to draw the remaining sides of the figure tangent to the circle and at 30° to the horizontal.

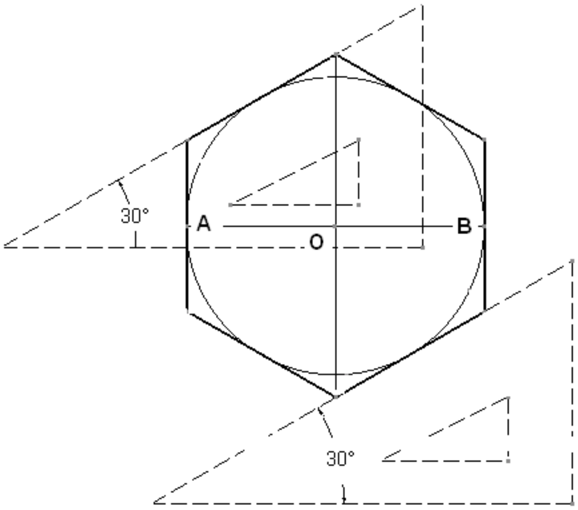


Figure 23 – Regular hexagon on a given inscribed circle

5.6 TANGENT

5.6.1 CIRCLE THROUGH THREE POINTS

In figure 24 the problem is to draw a circle (or a circular arc) that passes through points A B and C. Connect the points by lines and erect perpendicular bisectors as shown. The point of intersection of the perpendicular bisectors (O) is the center of the circle or arc passing through all three points.

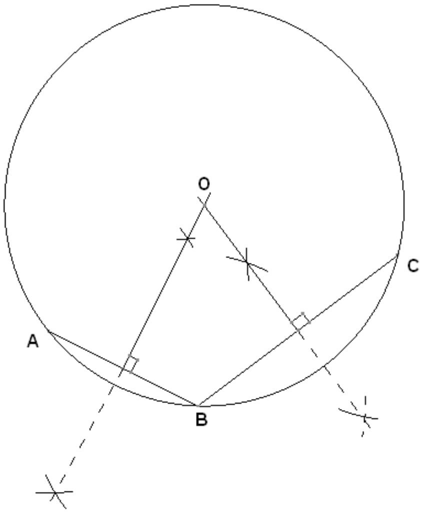


Figure 24 – Circle or arc through three points

5.6.2 CIRCULAR ARC OF A GIVEN RADIUS TANGENT TO TWO OTHER CIRCULAR ARCS

The problem in figure 25 is to draw an arc with a radius equal to AB, tangent to the circular arcs CD and EF. Set a compass to a spread equal to the radius of arc CD plus AB (indicated by the left-hand dashed line), and, with O as a centre, strike an arc. Set the compass to a spread equal to the radius of arc EF plus AB (indicated by the right-hand dashed line), and, with O´ as a centre, strike an intersecting arc. The point of intersection between the two arcs (P) is the centre of the circle of which an arc of given radius is tangent to arcs CD and EF.

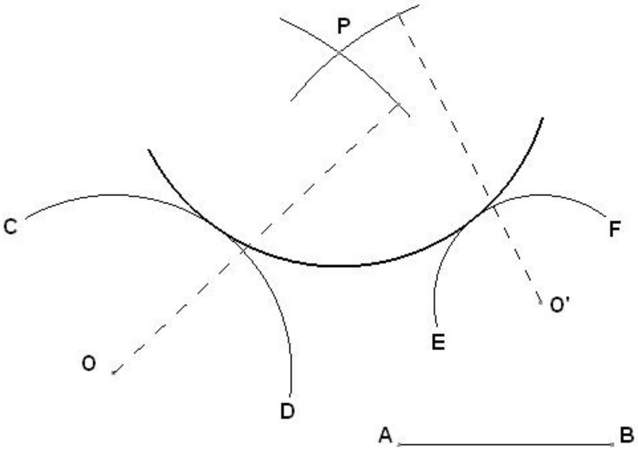


Figure 25 – Circular arc tangent to two other circular arcs

In figure 26 the circular arcs CD and EF curve in **OPPOSITE** directions. In figure 26 the problem is to draw an arc with radius equal to AB, tangent to two circular arcs, CD and EF, that curve in the **SAME** direction.
Set a compass to a radius equal to the radius of EF less AB, and, with O´ as a centre, strike an arc. Then, set a compass to a radius equal to the radius of arc CD plus line AB, and, with O as centre, strike an intersecting arc at P. The point of intersection of these two arcs is the centre of the circle of which an arc of the given radius is tangent to CD and EF.
When a circular arc is tangent to another, it is commonly the case that the two arcs curve in opposite directions. However, an arc may be drawn tangent to another with both curving in the same direction. In a case of this kind, the tangent arc is said to enclose the other.

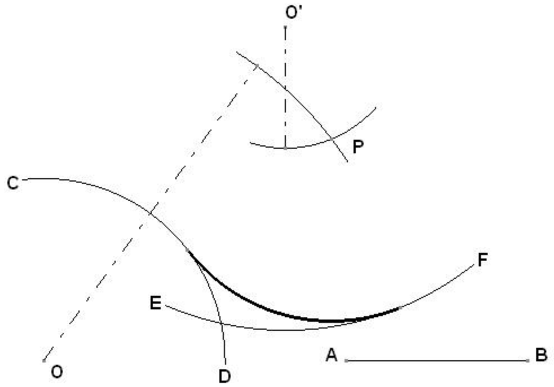


Figure 26 – Circular arc tangent to arcs that curve in the same direction

5.7 COMPOUND CURVES

A curve that is made up of a series of successive tangent circular arcs is called a compound curve. In figure 27 the problem is to construct a compound curve passing through given points A, B, C, D, and E. First, connect the points by straight lines. The straight line between each pair of points constitutes the chord of the arc through the points.

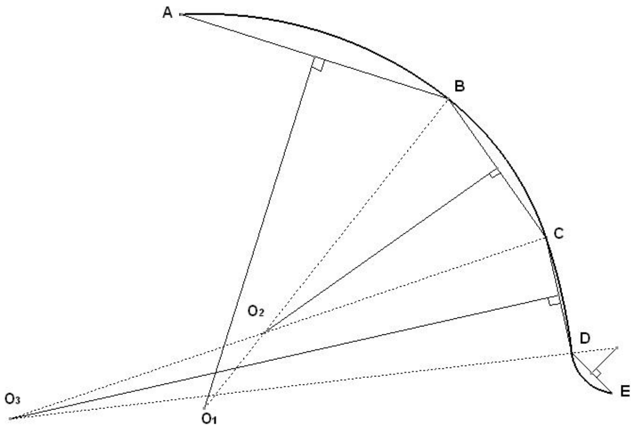


Figure 27 – Curve composed of a series of consecutive tangent circular arcs

Erect a perpendicular bisector from AB. Select an appropriate point O_1 on the bisector as a centre, and draw the arc AB. From O_1, draw the radius O_lB. From BC, erect a perpendicular bisector. The point of intersection 0_2 between this bisector and the radius O_lB is the centre for the arc BC. Draw the radius 0_2C, and erect a perpendicular bisector from CD. The point of intersection 0_3 of this bisector and the extension of 0_2C is the centre for the arc CD.

To continue the curve from D to E, you must reverse the direction of curvature. Draw the radius 0_3D, and erect a perpendicular bisector from DE on the opposite side of the curve from those previously erected. The point of intersection of this bisector and the extension of 0_3D is the centre of the arc DE.

5.7.1 REVERSE, OR OGEE, CURVE

A reverse, or ogee, curve is composed of two consecutive tangent circular arcs that curve in opposite directions.

Figure 28 shows a method of connecting two parallel lines by a reverse curve tangent to the lines. The problem is to construct a reverse curve tangent to the upper line at A and to the lower line at B.

Connect A and B by a straight line AB. Select on AB point C where you want to have the reverse curve change direction. Erect perpendicular bisectors from BC and CA, and erect perpendiculars from B and A. The points of intersection between the perpendiculars (0_1 and 0_2) are the centers for the arcs BC and CA.

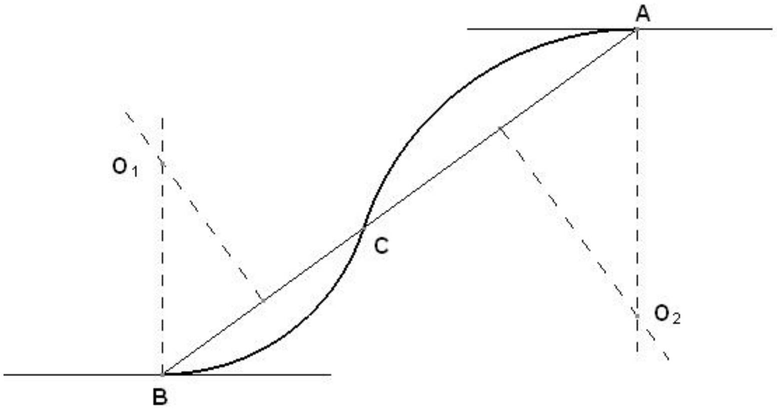


Figure 28 – Reverse curve connecting and tangent to two parallel lines

5.7.2 ELLIPSE BY FOUR-CENTER METHOD

The four-centre method is used for small ellipses. Given major axis, AB, and minor axis, CD, mutually perpendicular at their midpoint, O, as shown in figure 28, draw AD, connecting the end points of the two axes. With the dividers set to DO, measure DO along AO and reset the dividers on the remaining distance to O. With the difference of semi axes thus set on the dividers, mark off DE equal to AO minus DO. Draw perpendicular bisector AE, and extend it to intersect the major axis at K and the minor axis extended at H. With the dividers, mark off OM equal to OK, and OL equal to OH. With H as a centre and radius R_1 equal to HD, draw the bottom arc. With L as a centre and the same radius as R_1, draw the top arc. With M as a centre and the radius R_2 equal to MB draw the end arc. With K as a centre and the same radius, R_2, draw the end arc. The four circular arcs thus drawn meet, in common points of tangency, P, at the ends of their radii in their lines of centres.

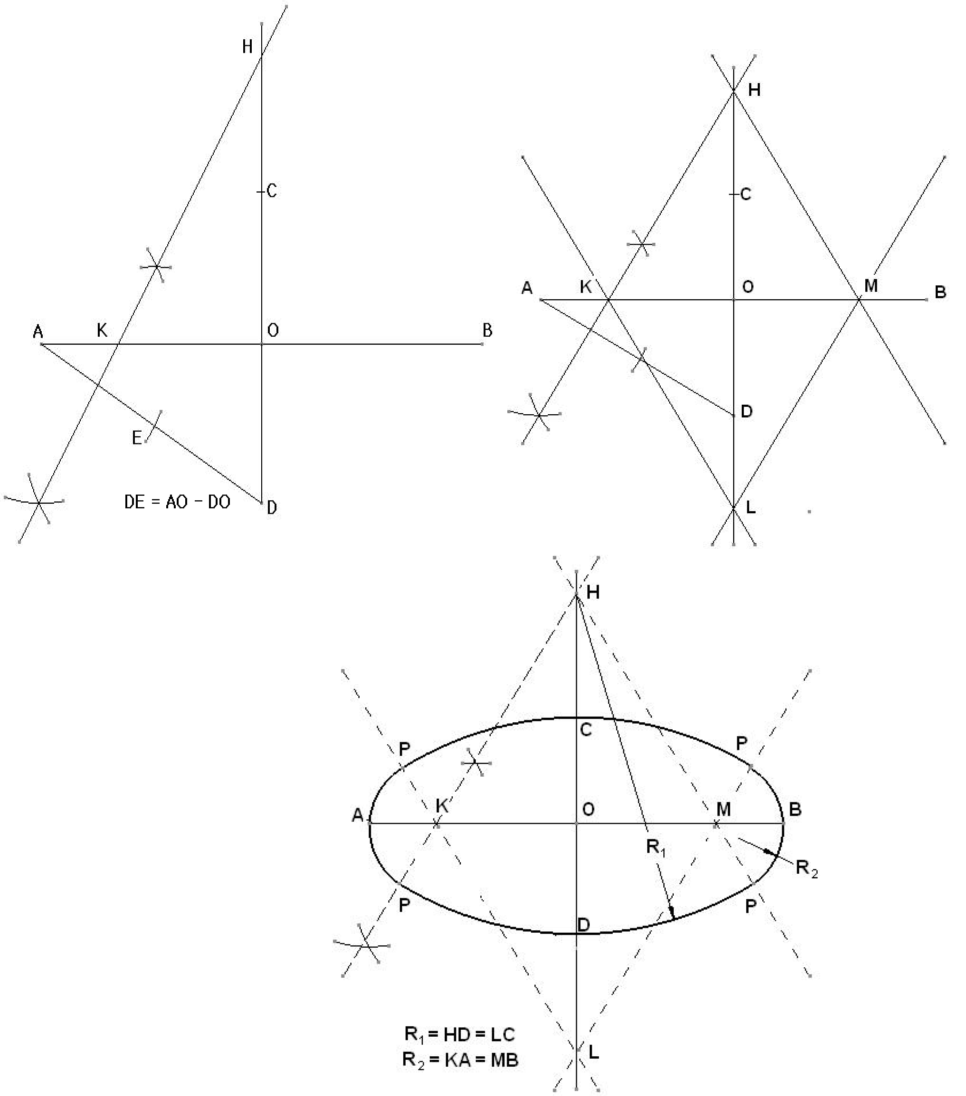


Figure 29 – Ellipse by four-centre method

6.0 PROJECTION SYSTEMS

INTRODUCTION

Behind every drawing of an object is a space relationship involving four imaginary things.

- The observer's eye, or the station point
- The object
- The plane or planes of projection
- The projectors, also called visual rays and lines of sight

There are 2 main types of projections:

(a) ***Perspective*** – when an observer is relatively close to the object and the projectors form a "cone" of projectors.

(b) ***Parallel*** – when an observer's eye is imagined as infinitely distant from the object and the plane of projection, the projectors will be parallel.

i. If the projectors, in addition to being parallel to each other, are perpendicular (normal) to the plane of projection P, the result is an *orthographic projection*, or right-angle projection.

ii. If the projectors are parallel to each other but oblique to the plane of projection, the result is an *oblique projection*.

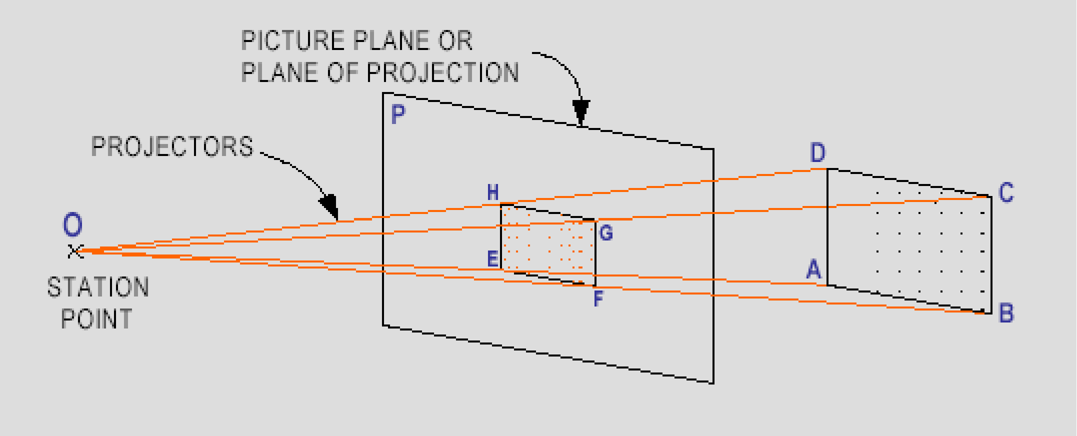


Figure 30 – Perspective

- EFGH is the projection of the square ABCD (the object) on the plane of projection P as viewed by the observer whose eye is at point O (Figure 30).

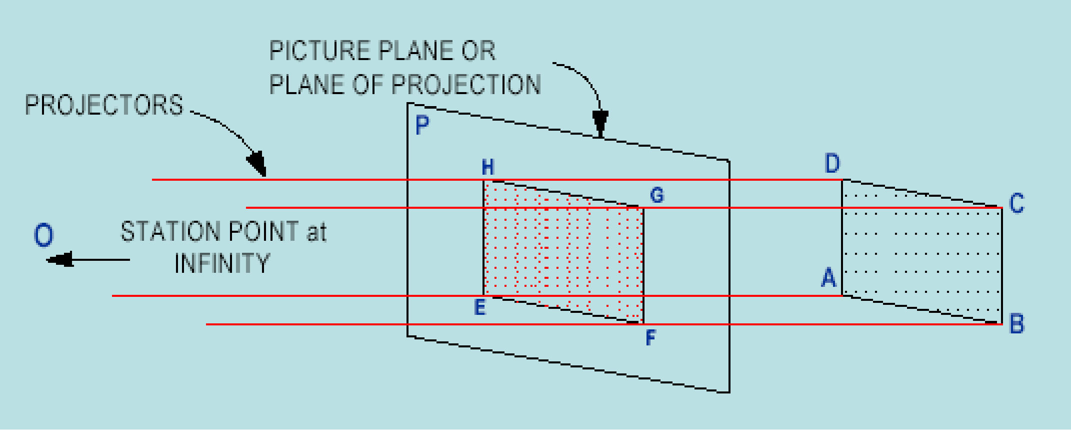


Figure 31 – Parallel

- EFGH is the projection of the square ABCD (the object) on the plane of projection P as viewed by the observer whose eye is imagined as infinitely distant from the object and the plane of projection (figure 31).

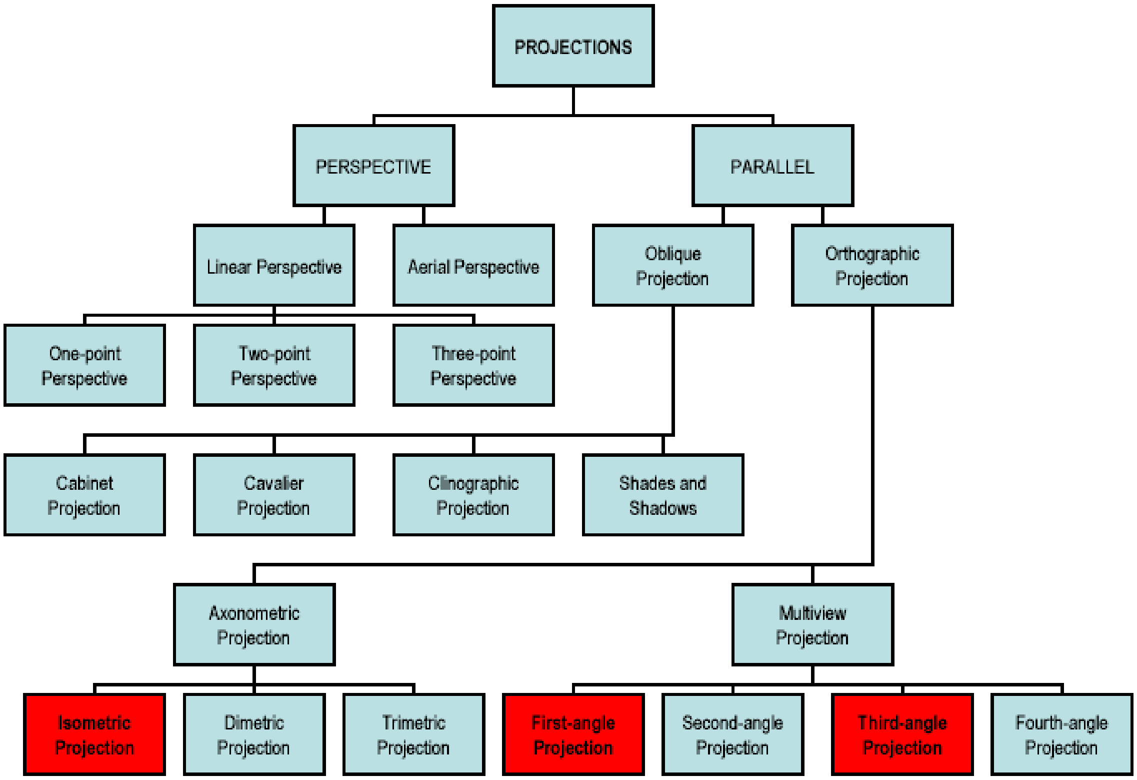


Figure 32 – Classification of Projections

6.1 ORTHOGRAPHIC PROJECTIONS

Orthographic views of any object can be represented by any one of the two systems of projections:

- (a) first angle projection, and
- (b) third angle projection

These are named according to the quadrant in which the object is imagined to be placed, for purposes of projection. The shape and size of views are same in these two systems. The only difference lies in the relative position of the various views.

6.1.1 FIRST ANGLE PROJECTION

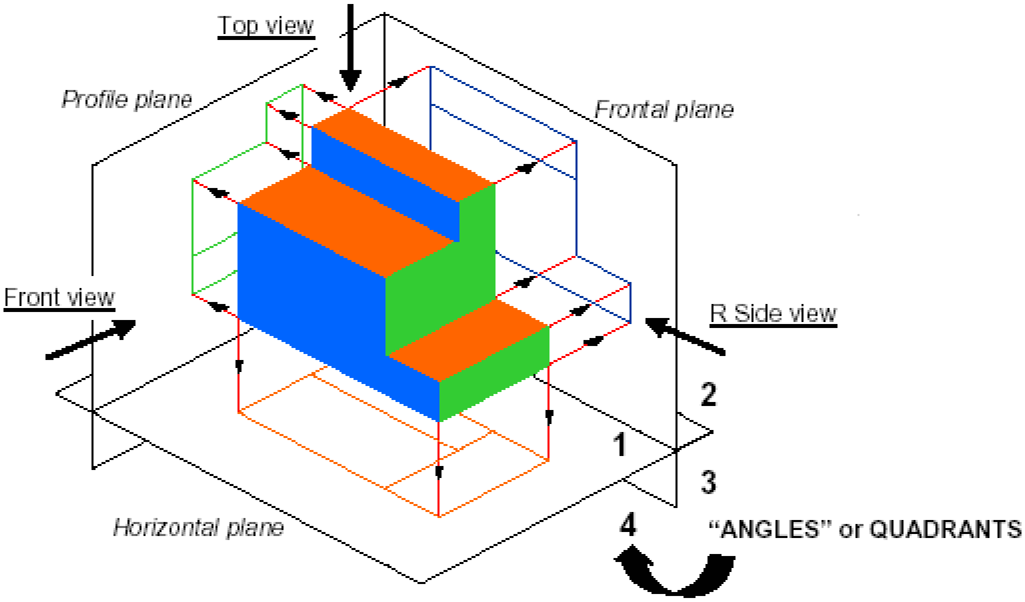


Figure 33 – Getting first and third angle projections

- Assume that a small block is made and two of its corners are cut, as shown in Figure 33 above

- If the *vertical (frontal)* and *horizontal planes* of projection are considered indefinite in extent and intersecting at 90^o with each other, the four dihedral angles produced are the ***first***, ***second***, ***third***, and ***fourth*** angles or quadrants.

- The *profile plane* intersects these two planes and may extent into all angles.

- If the object is placed above the horizontal plane and in front of the vertical (frontal) plane, the object is in the first angle. In this case, the observer always looks through the object and to the planes of projection.

- The right-side view is still obtained by looking toward the right-side of the object, the front by looking toward the front, and the top by looking down toward the top; but the views are projected from the object onto a plane in each case.

- Let say, when the planes are unfolded, the right-side view falls at the left of the front view, and the top view falls below the front view as shown in Figure 34.

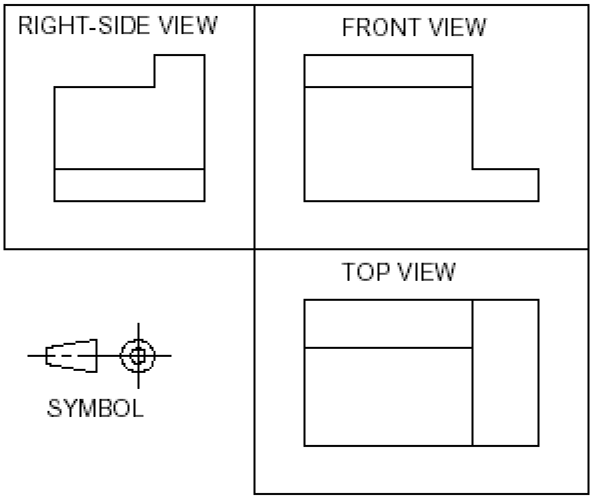


Figure 34 – First Angle Projection

6.1.2 THIRD ANGLE PROJECTION

- By referring to the Figure 34, if the object is placed below the horizontal plane and behind the vertical (frontal) plane, while the profile plane is moved in front of the object from the right side view, the object is said to be in the third angle. In this case, the observer is always "outside, looking in" so that for all views, the lines of sight proceed from the eye through the planes of projection and to the object.

- Let say, when the planes are unfolded, the right-side view falls at the right of the front view, and the top view falls above the front view as shown in Figure 35.

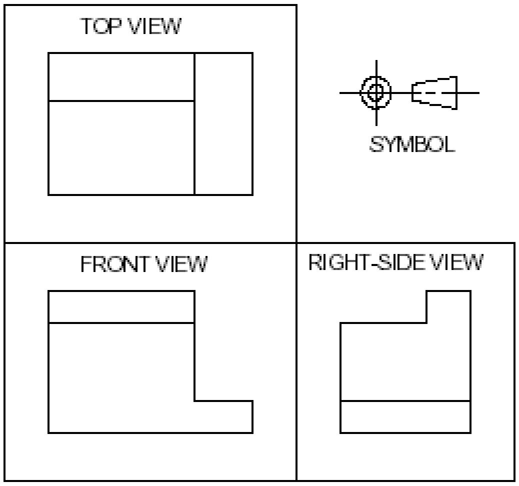
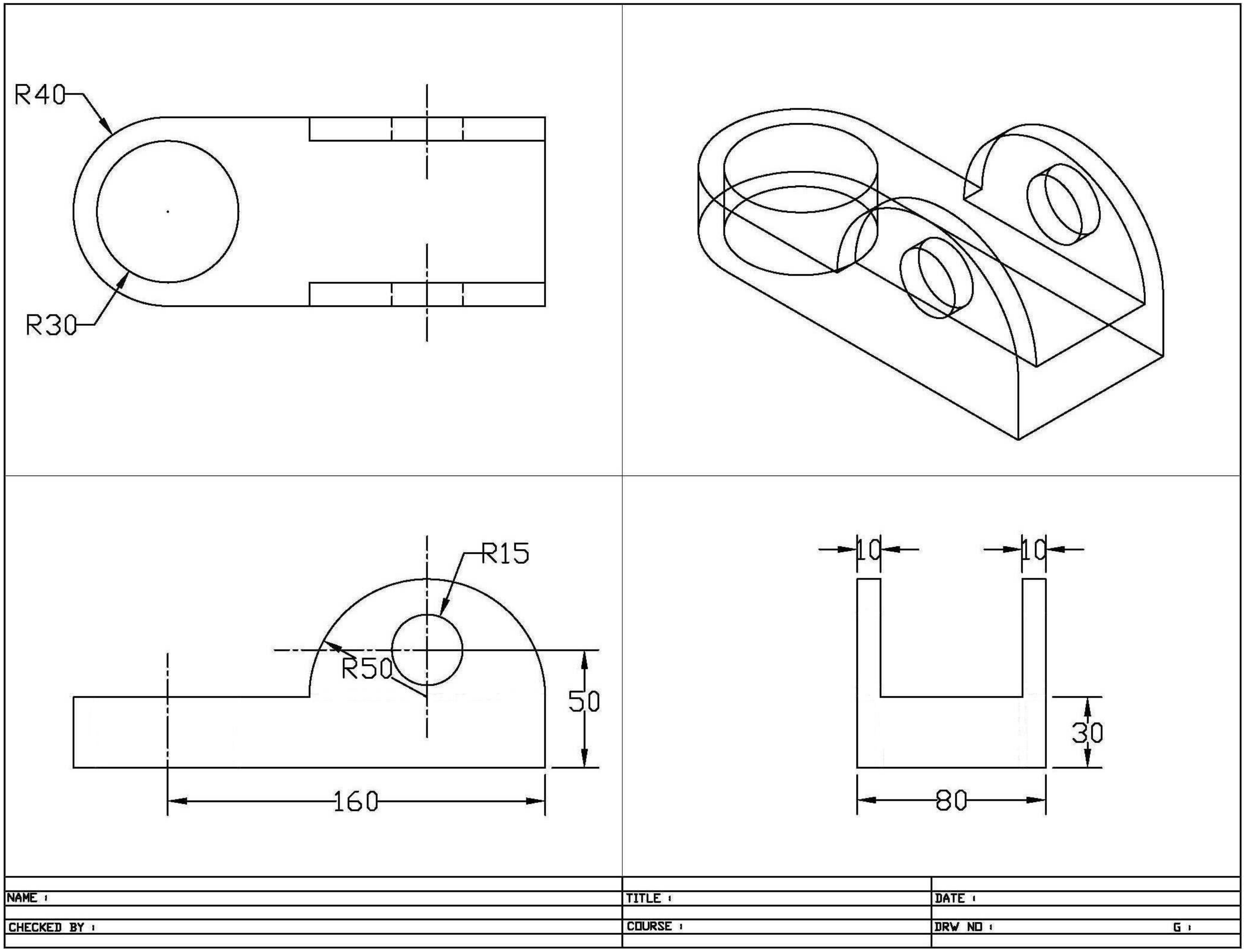


Figure 35 – Third Angle Projection

- It is important to understand that the only difference between the first angle and third angle projection is in the arrangement of the views.
- To avoid misunderstanding, international projection symbols have been developed to distinguish between first angle and third angle projections on drawings. On drawings, where the possibility of confusion is anticipated, these symbols may appear in or near the title box.
- In the United States and Canada, and to some extent in England, third angle projection is standard, while in most of the rest of the world, first angle projection is used.

6.2 EXERCISE 2 – ORTHOGRAPHIC (THIRD ANGLE PROJECTION)



6.3 ISOMETRIC PROJECTIONS

DEFINITION

- Isometric projection is one of the three forms of axonometric projection. In isometric projection for a cube, the angles between the projections of the axes are equal which is 120°.

- It is important to understand that it is the angles between the projection of the axes that are being discussed and not the true angles between the axes of the cube themselves which is always 90^o.

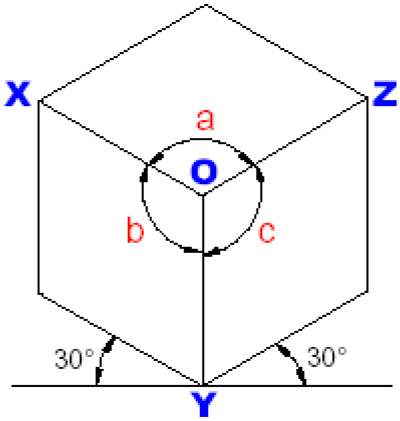


Figure 36 – An Example on Isometric Projection

- Isometric projection is produced using 3 axes which are the vertical axis (OY), left axis (OX) and right axis (OZ).

- The left and right axes are produced at the angle of 30^o to the horizontal line.

- The projections of the axes OX, OY and OZ make angles of 120o with each other and are called the ***isometric axes***.
  For example: a = b = c

  The dimensions of the cube in the direction of the 3 axes are equal;
  For example: OX = OY = OZ

6.3.1 STEPS IN MAKING AN ISOMETRIC DRAWING - RECTANGULAR BLOCK

- Figure 37 below shows the Plan View and the Front View of a rectangular block.

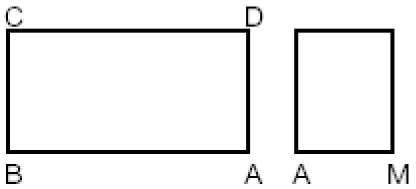


Figure 37 – Plan view and front view of a rectangular block

- AB and AM lines which are horizontal as in *orthographic projection* must be drawn with an angle of 30^o to the horizontal line for the *isometric projection*.
- AD line shall be drawn vertical, same for both the *orthographic* and *isometric projections*.
- Parallel lines as in *orthographic projection* are maintained for the *isometric projection*.
- Figure 38(a) – 38(d) shows the flow in constructing an *isometric projection* for a rectangular block.

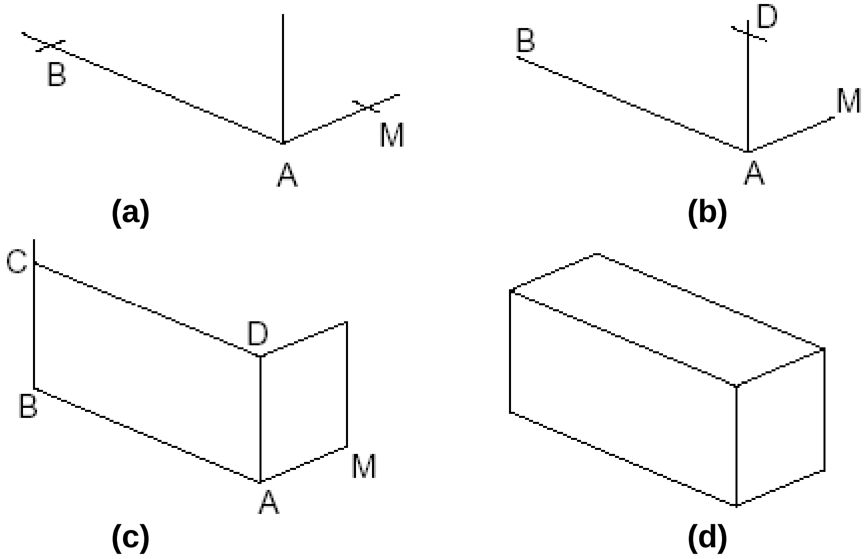


Figure 38 – Flow in constructing an isometric projection for a rectangular block

6.3.2 STEPS IN MAKING AN ISOMETRIC DRAWING – ELLIPSE

In isometric drawing, circle is drawn as an ellipse. There are 2 ways of constructing the ellipse from a circle in orthographic projection.

METHOD 1

- Draw a circle of radius R and a square as in Figure 39(a).
- Draw the square isometric projection of length 2R and identify the points ABCD as in Figure 39(b).
- Draw lines from point D and point B to one of the corners and identify as point S. These 2 lines will intercept with a line constructed from the other 2 corners and mark as point P and point Q.
- From point P, draw a curve of radius PA, and from point Q, draw a curve of radius QC.
- From point S, draw a curve of radius SD from point D to point B, and repeat the same method to obtain a curve from A to C from point R.

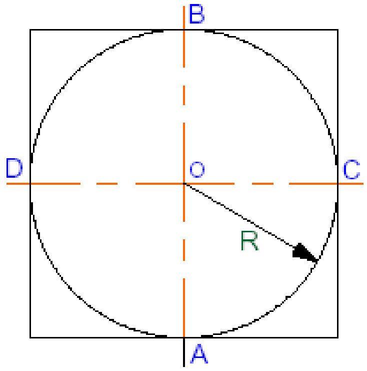


Figure 39(a)

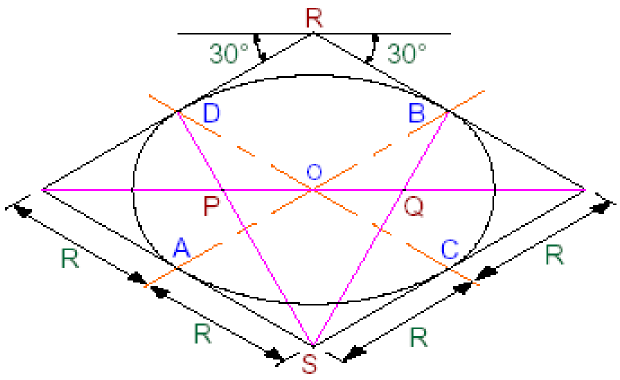
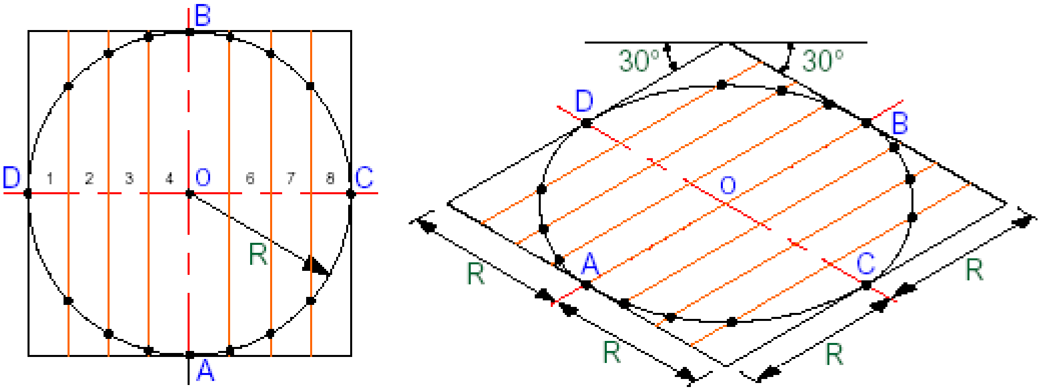


Figure 39(b)

METHOD 2

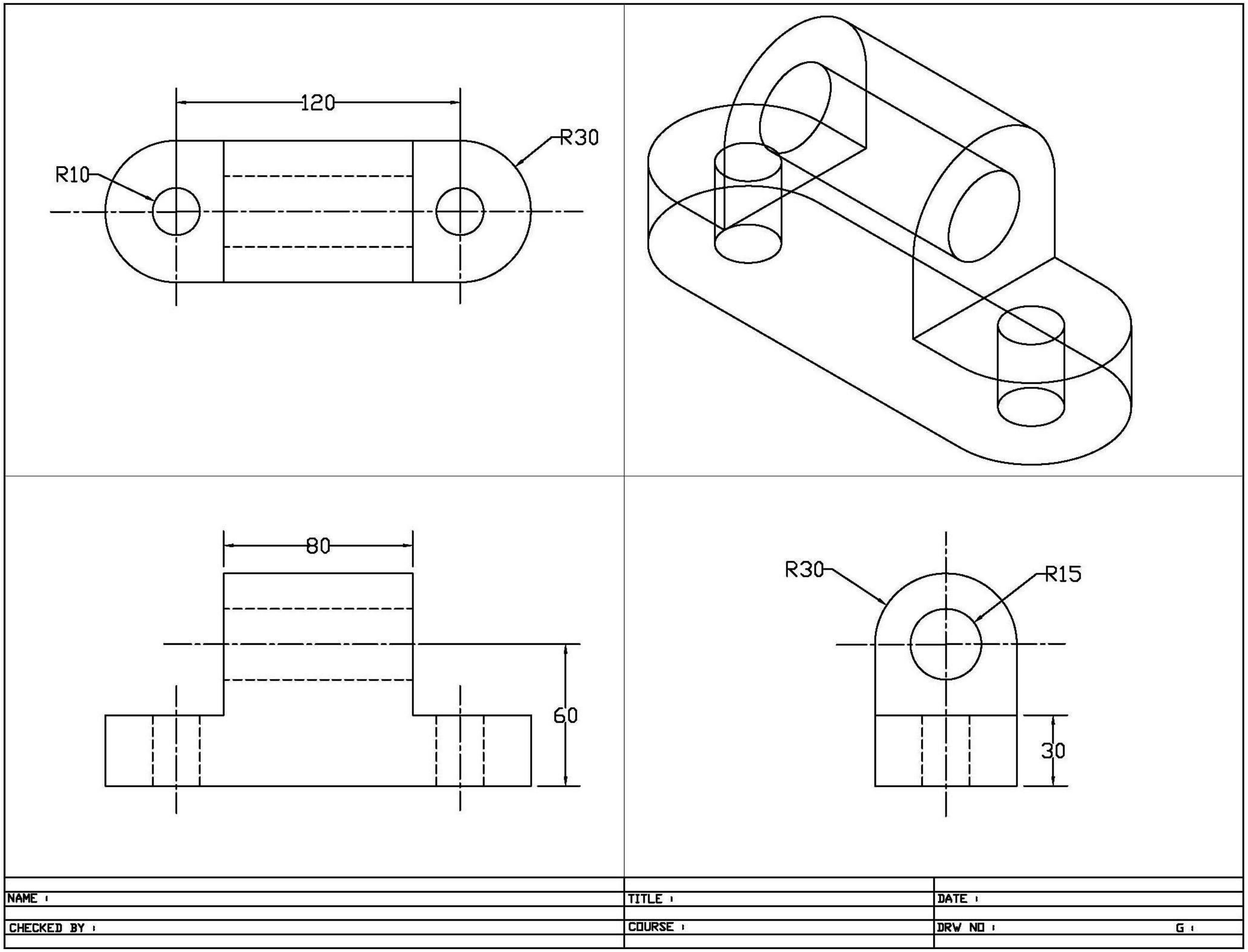
- Draw a circle of radius R and a square as in Figure 40(a).
- Divide the DC line to 8 equal sections.
- Draw the square isometric projection of length 2R and identify the points ABCD as in Figure 40(b).
- And again, divide the DC line to 8 equal sections and transfer the points from the orthographic projection to the isometric projection.
- Joint the points to produce an ellipse.



(a) **(b)**

Figure 40

6.4   EXERCISE 3 – ISOMETRIC PROJECTION



7.0 CONVENTIONAL LINES

As the basis of engineering drawing is a line, a set of conventional symbols representing all the lines are needed for different purposes or as an alphabet of lines. In Technical Drawings, the types of lines and their general applications, as recommended by most international standard are given in Table 1. These lines differ from each other in two respects:

1. Thickness or weight, for example, thick, medium, and thin.
2. Shape or construction, depending upon their conventional use.

Lines specified as *thick* should be about 3 times as thick as the *thin* lines and lines specified as *medium* should be 1.5 times as thick as the *thin* lines.

For all views of one piece to the same scale, the thickness of the lines should be same. Owing to difficulties in methods of reduction, the line thickness of 0.18 mm should be avoided. The minimum space between parallel lines, including hatching, should never be less than twice the thickness of heaviest line. It is further recommended that these spaces should never be less than 0.7 mm.

7.1 VISIBLE LINE OR OBJECT LINE

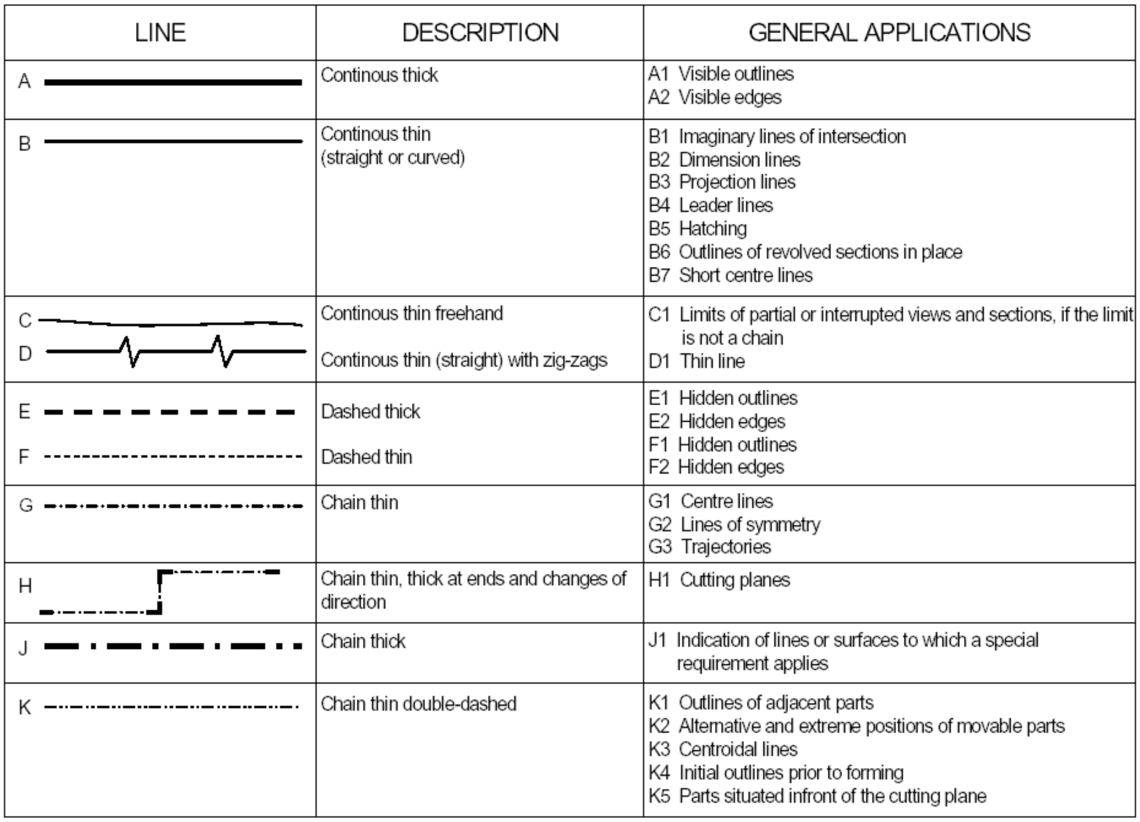
Outline is an outstanding feature in any drawing. These are thick, continuous lines and are used to represent the outline or overall shape of an object. Every edge or surface that is visible is represented by these lines.

7.2 SECTION LINES

These are thin continuous lines, uniformly spaced and are used to show a part in section. These lines are usually drawn at an angle of 45^o (may be 60^o or 30^o) to the horizontal. These lines extend edge to edge of the surface in which these are drawn.

7.3 CONSTRUCTION LINES

These are faint continuous lines used for projecting or transferring locations from one view to the other and for constructing drawings. These lines do not appear in finished drawings, except in Geometrical Drawings where these are usually not removed.



LINE	DESCRIPTION	GENERAL APPLICATIONS
A	Continous thick	A1 Visible outlines A2 Visible edges
B	Continous thin (straight or curved)	B1 Imaginary lines of intersection B2 Dimension lines B3 Projection lines B4 Leader lines B5 Hatching B6 Outlines of revolved sections in place B7 Short centre lines
C	Continous thin freehand	C1 Limits of partial or interrupted views and sections, if the limit is not a chain
D	Continous thin (straight) with zig-zags	D1 Thin line
E	Dashed thick	E1 Hidden outlines E2 Hidden edges
F	Dashed thin	F1 Hidden outlines F2 Hidden edges
G	Chain thin	G1 Centre lines G2 Lines of symmetry G3 Trajectories
H	Chain thin, thick at ends and changes of direction	H1 Cutting planes
J	Chain thick	J1 Indication of lines or surfaces to which a special requirement applies
K	Chain thin double-dashed	K1 Outlines of adjacent parts K2 Alternative and extreme positions of movable parts K3 Centroidal lines K4 Initial outlines prior to forming K5 Parts situated infront of the cutting plane

Table 1 – Types of Lines and Their General Application

7.4 HIDDEN LINES

Shape which cannot be seen, when an object is looked at from an outside viewing position, can be drawn in hidden detail. It is not necessary to include all hidden detail in views but only sufficient hidden detail need to be included to show quite clearly the exact shape of the object. Hidden lines may also be omitted, when not required in order to preserve the clarity of the drawing.

When adding hidden detail lines to a drawing, the following rules should be followed:

- In general, a hidden line should join a visible line except when it causes the visible line to extent too far. In other words, *leave a gap whenever a hidden-line dash forms a continuation of a visible line* – Figure 41(a)
- Hidden lines should intersect to form L and T corners – Figure 41(b)
- A hidden line preferably should “jump” visible line when possible – Figure 41(c)
- Parallel hidden lines should be drawn so that the dashes are staggered, in a manner similar to bricklaying – Figure 41(d)
- When two or three hidden lines meet at a point, the dashes should join together – Figure 41(e)(f)
- For drawing hidden arcs, the lines should join the visible lines.

Each dash should be carefully drawn about 5 mm long and spaced only about 1 mm apart by eye.

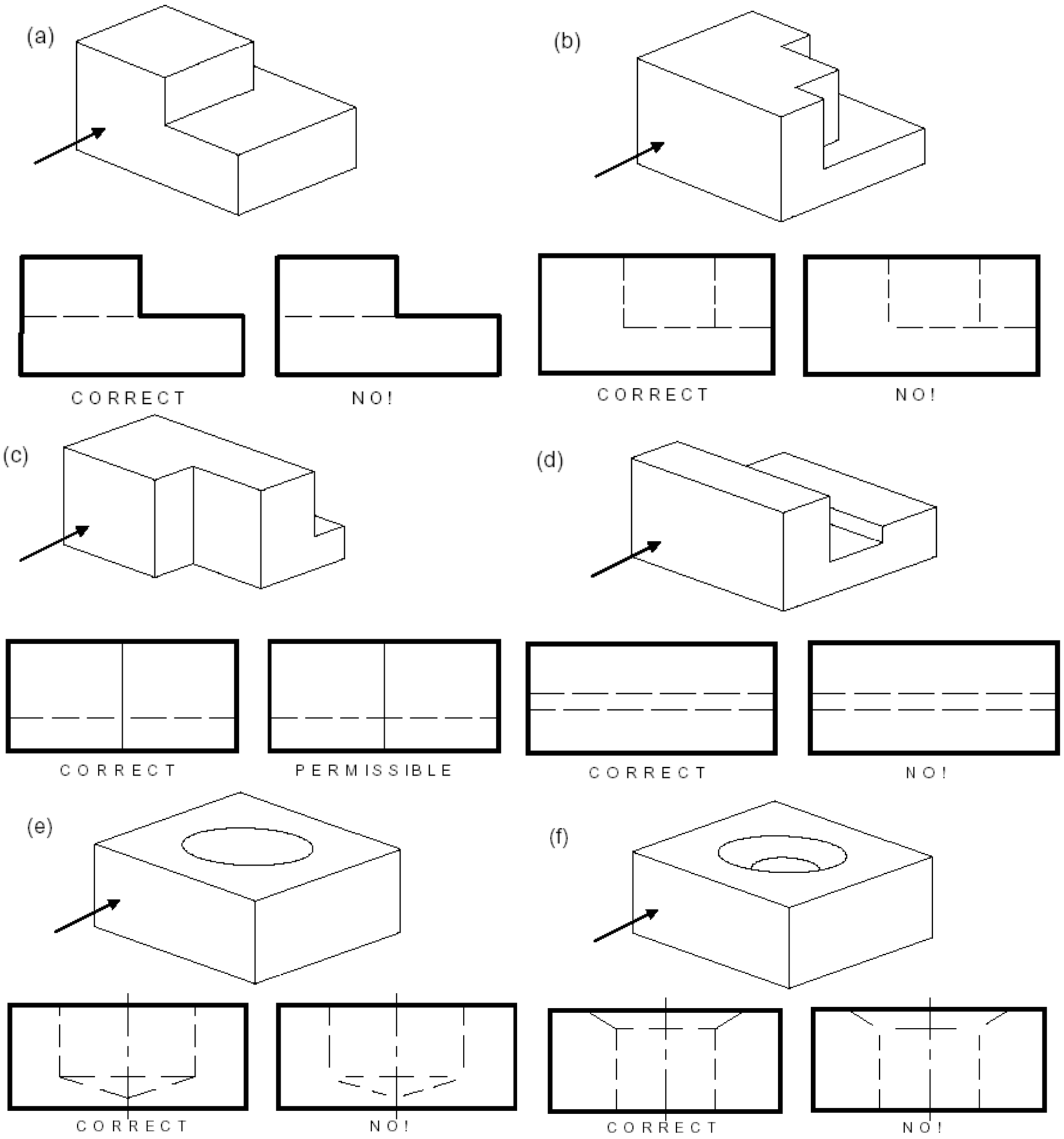

(a)
CORRECT
NO!
(b)
CORRECT
NO!
(c)
CORRECT
PERMISSIBLE
(d)
CORRECT
NO!
(e)
CORRECT
NO!
(f)
CORRECT
NO!

Figure 41

7.5 CENTRE LINES

These lines are represented by long and short dashes. The proportion for these long and short dashes is ranging from 6:1 to 4:1. In any one drawing the proportion selected should be maintained by eye judgment.

The centre lines are used to centre the symmetrical views of circular parts, to indicate centre points, axes of symmetrical parts, axes of symmetry and also for giving the location dimension. These lines are first to be drawn in any drawing after carefully spacing the various views to be drawn.
Following points need special care when drawing centre lines:

- Where two centre lines cross, the short dashes should intersect symmetrically, as shown for circle in Figure 42.
- When a centre line coincides with either a visible or a hidden line, it should not be continued into such a line.
- No centre line should begin or end at the lines representing surfaces of the object, but should extend about 5 mm beyond such surfaces.
- Centre lines should be drawn for all parts, visible or hidden, which have these lines.
- Centre lines should begin and end with a long dash.
- Centre lines should not extend between views in an orthographic projection.
- Centre line should not be used as dimension lines for the purpose of dimensioning, but may be extended for the purpose of dimensioning.
- Centre lines should extend for a short distance beyond the feature unless they are required for dimensioning or some other purpose.
- If an angle is formed by chain lines, then the long dashes should intersect and define the angle.

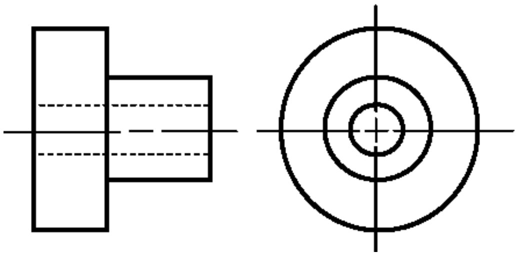


Figure 42

7.6 CUTTING PLANE LINES

These lines are made up of alternately a long dash and a short dash in the ratio of about 6:1 to 4:1 and are drawn as centre lines but are extra thick at ends and having arrows touching them. They are used to show the edge of the cutting plane when an object is being sectioned to show the hidden details. The arrows, attached to the ends of such lines indicate the direction in which the section is to be seen.

7.7 BREAK LINES

7.7.1 Short Breaks and Irregular Boundary Lines

These are thin lines drawn freehand and are used to show a break of an object which extends over a short length of the drawing or to indicate the irregular boundary of an object. These result in a saving in space and time used for drawing without loss of details.

7.7.2 Long Breaks

These are thin ruled lines having freehand zigzags at suitable intervals and are used when the break extends over a considerable length of the drawing.

7.8 LONG CHAIN THICK LINES

Composed of alternate long and short dashes and are used to indicate surfaces which are to receive additional treatment.

8.0 REFERENCES

[1] http://www.tpub.com

[2] http://www.tpub.com/content/engineering/14069/css/14069_89.htm

[3] http://www.khulsey.com/portfolio_auto.html